Miscellaneous Effects

Maskarinec G, Cooper J, Swygert L. Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. J Environ Pathol Toxicol Oncol. 13(1):33-37, 1994.

Twelve children from the Waianae Coast, Hawaii, were diagnosed with acute leukemia from 1979 to 1990. The standardized incidence ratio (SIR) of 2.09 (95% confidence interval (CI) 1.08 to 3.65) indicates a significant increase. Seven cases occurred between 1982 and 1984 and were unusual in terms of sex, age, and type of leukemia. A case-control study (12 cases, 48 matched controls) explored risk factors, including parents' occupation, X-ray exposure, domestic smoking, family and medical histories, and distance of children's residence locations to low frequency radio towers. The odds ratio (OR) for having lived within 2.6 miles of the radio towers before diagnosis was 2.0 (95% CI 0.06 to 8.3). The clustering may have been a chance event, but because of its peculiar characteristics, we feel it should be noted.

Johnson Liakouris AG, Radiofrequency (RF) sickness in the Lilienfeld Study: an effect of modulated microwaves? Arch Environ Health 53(3):236-238, 1998.

There is a controversy among professionals regarding whether radiofrequency radiation sickness syndrome is a medical entity. In this study, this controversy was evaluated with a methodology adapted from case studies. <u>The author reviewed U.S. literature, which revealed that research results are sufficiently consistent to warrant further inquiry. A review of statistically significant health effects noted in the Lilienfeld Study provided evidence that the disregarded health conditions match the cluster attributed to the radiofrequency sickness syndrome, thus establishing a possible correlation between health effects and chronic exposure to low-intensity, modulated microwave radiation. The author discusses these health effects relative to (a) exposure parameters recorded at the U.S. Embassy in Moscow and (b) the Soviet 10-microwatt safety standard for the public. Given the evidence, new research-with current knowledge and technology-is proposed.</u>

Isa AR, Noor M, Non-ionizing radiation exposure causing ill-health and alopecia areata. Med J Malaysia 46(3):235-238, 1991.

<u>Three cases of occupational exposure to radio-frequency and microwave radiation were seen at the out-patient clinic, Hospital Universiti Sains Malaysia. They presented with run-down symptoms of neck strain associated with throbbing headache, irritability, loss of appetite, fatigue, memory difficulties, and numbness of extremities. They also presented with alopecia areata which is felt to be causally linked to the radiation exposure.</u>

Afromeev VI, Tkachenko VN, [Change in the percent of lactate dehydrogenase

isoenzyme level in testes of animals exposed to superhigh frequency radiation]. Biofizika 44(5):931-932, 1999. [Article in Russian]

The content of six lactate dehydrogenase isoenzymes in testes of rats exposed to electromagnetic field of 3-cm wavelength range was studied. The changes in their percent contents were found to be inhomogeneous compared with control. It is assumed that electromagnetic radiation affects the organs of the human urinogenital system. The results can be used for estimating the safety of persons professionally exposed to electromagnetic radiation of the industrial frequency range and in the therapy of diseases of the urinogenital system.

Anghileri LJ, Mayayo E, Domingo JL. Aluminum, calcium ion and radiofrequency synergism in acceleration of lymphomagenesis. Immunopharmacol Immunotoxicol. 31(3):358-362. 2009

This study that was done on lymphomagene-bearing mice indicates a synergism aluminum-radiofrequency which induces an early increase in mortality that is in concomitance with lymphoid elements proliferation and infiltration of spleen and liver. These two last phenomena were assesed by determination of the hypertrophic index (Growth Index) which is the organ weight to to the body weight ratio, as well as by the histopathological examination of the organ tissue. The importance of this synergism appears to be determined by the ionization at the physiological pH of the used aluminum complexes: much higher with lactate complex than with the citrate one. On the other hand, this dissociation appears to induce a remarkable acceleration of the mortality and the lymphoid elements-related hypertrophy of the spleen and liver at early age. Aluminum complexes are known as modifiers of the intracellular calcium homeostasis, and to verify if such process could be implicated in this synergism, the effects of calcium chloride were assayed, in this case the calcium-overload had no effects in the presence of a workable cellular control of intracellular calcium homeostasis. This finding support the hypothesis that ionized aluminum provided by lactate may be implicated in the inhibition of the buffering and extruding extracellular calcium system.

Apollonio F, D'Inzeo G, Tarricone L. Energy evaluation of mw effects on Ach receptor channels with parallel computing Electromag. Biol. Med. 19:69-79, 2000.

We present an evaluation of the effects of microwave fields on the acetylcholine (ACh) receptor channel, based on energy issues. The channel is considered a stochastic automaton, flipping randomly from one state to another, and the incident field modifies transitions among the states. The observation of some appropriate biochemical parameters demonstrates that microwave fields cause conformational changes in the receptor site. An energetic mapping of ACh conformational changes is also achieved, clearing the ground for future development of this research in the field of molecular simulations.

Baste V, Moen BE, Oftedal G, Strand LA, Bjørge L, Mild KH. Pregnancy Outcomes After Paternal Radiofrequency Field Exposure Aboard Fast Patrol Boats. J Occup Environ Med. 54(4):431-438, 2012.

OBJECTIVES: To investigate adverse reproductive outcomes among male employees in the Royal Norwegian Navy exposed to radiofrequency electromagnetic fields aboard fast patrol boats. METHODS: Cohort study of Royal Norwegian Navy servicemen linked to the Medical Birth Registry of Norway, including singleton offspring born between 1967 and 2008 (n = 37,920). Exposure during the last 3 months before conception (acute) and exposure more than 3 months before conception (nonacute) were analyzed. RESULTS: Perinatal mortality and preeclampsia increased after service aboard fast patrol boats during an acute period and also after increased estimated radiofrequency exposure during an acute period, compared with service aboard other vessels. No associations were found between nonacute exposure and any of the reproductive outcomes. CONCLUSIONS: Paternal work aboard fast patrol boats during an acute period was associated with perinatal mortality and preeclampsia, but the cause is not clear.

Belokhvostov AS, Osipovich VK, Veselova OM, Kolodiazhnaia VA. [DNA analysis of retroposon-like genetic LINE elements in blood plasma of rats exposed to radio-diapason electromagnetic waves] Radiats Biol Radioecol 35(3):356-363, 1995. [Article in Russian]

The elevation of LINE-elements' DNA level was revealed in blood plasma of rats exposed to electromagnetic waves. The amount of full-size 5'-containing LINE-elements copies was increased especially. Connection of this effect with retrotransposon activation and genetic instability condition of organism development is supposed.

Belousova TE, Kargina-Terent'eva RA, [Adrenergic nerve plexuses of heart and adrenal and myocardial catecholamines of spontaneously hypertensive rats under the influence of electromagnetic irradiation in the millimeter range]. Morfologiia 115(1):16-18, 1999. [Article in Russian]

Condition of adrenergic cardiac and adrenal nervous plexuses of Kyoto-Wistar Rats (WKY) and spontaneously hypertensive rats (SHR) was examined by quantitative neurohistochemical methods before and after extremely high frequency field (EHF field) influence of "Bayur" microwave therapy apparatus in mode 1 (42,194 MHz frequency, 7.1 mm wavelength) and in mode 3 (53,534 MHz frequency, 5.6 mm wavelength). Reduction of myocardial nervous plexus density and catecholamine luminescence intensity were detected in SHR, as well as decrease of adrenal glands relative weight and catecholamine luminescence intensity in adrenal medulla of SHR, that is indicative of suppression of sympatho-adrenal system of hypertensive animals by EHF field influence in medical operating modes.

Belyaev IY, Shcheglov VS, Alipov YD, Polunin VA, Resonance effect of millimeter waves in the power range from 10(-19) to 3 x 10(-3) W/cm2 on Escherichia coli cells at different concentrations. Bioelectromagnetics 17(4):312-321, 1996.

The effect of millimeter waves (MMWs) on the genome conformational state (GCS) of E. coli AB1157 cells was studied by the method of anomalous viscosity time dependencies (AVTD) in the frequency range of 51.64-51.85 GHz. The 51.755 GHz resonance frequency of the cell reaction to MMWs did not depend on power density (PD) in the range from 10(-19) to 3 x 10(-3) W/cm2. The half-width of the resonant reaction of cells showed a sigmoid dependence on PD, changing from 3 MHz to 100 MHz. The PD dependence of the half-width had the same shape for different concentrations of exposed cells (4 x 10(7) and 4 x 10(8) cells/ml), whereas the magnitude of the 51.755 GHz resonance effect differed significantly and depended on the PD of MMW exposure. Sharp narrowing of the 51.755 GHz resonance in the PD range from 10(-4) to 10(-7) W/cm2 was followed by an emergence of new resonance frequencies. The PD dependence of the MMW effect at one of these resonance frequencies (51.674 GHz) differed markedly from the corresponding dependence at the 51.755 GHz resonance, the power window occurring in the range from 10(-16) to 10(-8) W/cm2. The results obtained were explained in the framework of a model of electron-conformational interactions. The frequency-time parameters of this model appeared to be in good agreement with experimental data.

Betts TR, Simpson IA, Inhibition of temporary pacing by a mobile phone. Heart 87:130, 2002.

A patient with no underlying rhythm was receiving transvenoustemporary pacing from an external pulse generator and bipolartemporary pacing wire on a coronary care unit. While examiningthe patient, the consultant cardiologist was telephoned on hismobile phone, carried in his jacket pocket. The electromagneticinterference generated by the ringing mobile phone caused inappropriatesensing by the pulse generator and inhibition of ventricularpacing. The image shows the resultant 2.5 second pause. Pacingrecommenced when the mobile phone was moved away from the bedside.This case is a reminder that mobile phones may adversely affectelectronic hospital equipment.

Blick DW, Adair ER, Hurt WD, Sherry CJ, Walters TJ, Merritt JH, Thresholds of microwave-evoked warmth sensations in human skin. Bioelectromagnetics 18(6):403-409, 1997.

We measured thresholds for microwave-evoked skin sensations of warmth at frequencies of 2.45, 7.5, 10, 35, and 94 GHz. In the same subjects, thresholds of warmth evoked by infrared radiation (IR) were also measured for comparison. Detection thresholds were measured on the skin in the middle of the back in 15 adult male human subjects at all microwave (MW) frequencies and with IR. Long duration (10-s), large area (327-cm2) stimuli were used to minimize any differential effects of temporal or spatial summation. Sensitivity increased monotonically with frequency throughout the range of microwave frequencies tested. The threshold at 94 GHz (4.5 +/- 0.6 mW/cm2) was more than an order of magnitude less than at 2.45 GHz (63.1 +/- 6.7 mW/cm2), and it was comparable to the threshold for IR (5.34 +/- 1.07 mW/cm2).

Bodera P, Stankiewicz W, Antkowiak B, Paluch M, Kieliszek J, Sobiech J, Zdanowski R, Wojdas A, Siwicki AK, Skopińska-Rózewska E. Suppressive effect of electromagnetic field on analgesic activity of tramadol in rats. Pol J Vet Sci. 15(1):95-100, 2012.

The electromagnetic fields (EMFs) have been shown to alter animal and human behavior, such as directional orientation, learning, pain perception (nociception or analgesia) and anxiety-related behaviors. The aim of this study was to evaluate the influence of electromagnetic fields of high-frequency microwaves on pain perception and anti-nociceptive activity of tramadol (TRAM) - analgetic effective in the treatment of moderate to severe acute and chronic pain states. Electromagnetic fields exposures of a)1500 MHz frequency and b) modulated, 1800 MHz (which is identical to that generated by mobile phones) were applied. Paw withdrawal latency (PWL) to thermal stimulus was measured in vehicle or tramadol (TRAM) treated animals before and after 30, 60 and 90 minutes from injections. The differences in the level of pain (PWL) between control group and rats exposed to EMF alone in three measurements, were not observed. Tramadol alone significantly increased PWLs to thermal stimulus in comparison to vehicle results at 30 ($p < 0.001$) and 60 minutes ($p < 0.05$) after drug injection. EMF exposure of both frequencies transiently suppressed analgesic effect of tramadol, significantly reducing paw withdrawal latency in animals treated with this drug at 30 minutes from the drug injection.

Bohr, H, Bohr, J, Microwave enhanced kinetics observed in ORD studies of a protein. Bioelectromagnetics 21(1):68-72, 2000.

Microwaves are shown to affect the kinetics of conformational changes of the protein beta-lactoglobulin. Microwaves can accelerate conformational changes in the direction towards the equilibrium state. This applies both for the folding and the unfolding processes. Cold denaturing thermal unfolding of the proteins is accelerated by negative temperature gradients. Microwave irradiation of the protein solution heated it by about 0.3 degree, and hence the observed acceleration of denaturing is therefore non-thermal.

Bortkiewicz A, Zmyslony M, Gadzicka E, Szymczak W, [Evaluation of selected parameters of circulatory system function in various occupational groups exposed to high frequency electromagnetic fields. II. Electrocardiographic changes]. Med Pr 47(3):241-252, 1996. [Article in Polish]

The effect of electromagnetic fields (EMF) on the circulatory and nervous systems has been the subject of great interest for many years, since electric impulses generated in these systems by outer electric and magnetic fields can theoretically disturb their functions. The only data on chronic effect of weak EMFs on the human body come from the studies carried out in the Soviet Union between the fifties and the seventies. In view of a growing number of persons exposed to EMF, there is an urgent need for verifying those data by means of modern diagnostic methods. That is the reason why our study of the EMF effect on the circulatory system has been initiated. It covered 71 workers at four AM broadcast stations, 40 workers at ten radio link stations and 42 workers at three radioservices. Workers' exposure to EMF was evaluated (see part I). Subjective and objective medical examinations were performed in all workers in order to assess their state of health, then resting electrocardiogram, Holter measurements, and high intensity ECG were taken, and variation in cardiac rhythm was analysed by a long-term recording of blood pressure. The results of the analysis of the questionnaire survey as well as the Holter and resting ECG examinations are presented. The study indicated that exposure to EMF in parameters found in AM broadcast station increased risk for electrographic disturbances (detected by means of resting ECG and a 24-hour Holter recording) by six times in comparison with that in radio link station workers not exposed to medium wave EMF. In radioservice workers this risk was twice as high as that in link station workers. It seems that in AM broadcast station workers, resting ECG should be complemented by a 24-hour Holter measurements, particularly, if workers complain of the circulatory system disturbances.

Bortkiewicz A, Gadzicka E, Zmyslony M, Heart rate variability in workers exposed to medium-frequency electromagnetic fields. J Auton Nerv Syst 59(3):91-97, 1996

This study was undertaken to evaluate the neurovegetative regulation of the heart in workers occupationally exposed to medium frequency (MF) electromagnetic (EM) fields. The subjects were 71 workers of MF broadcast stations, aged 20-68 (mean 47.1) with the duration of work under exposure ranging from 2-40 years and 22 workers of radio link stations, aged 21-65 (mean 46.9) who were not exposed to MF EM fields. The distribution of age and work tenure in both groups did not differ significantly. Heart rate variability (HRV) was analysed basing on 512 normal heart evolutions registered in resting, from the body surface, using the Medea-HRV system. The analysis concerned time-domain and frequency-domain parameters of HRV using fast fourier transformation. Power spectrum in the low (0.05-0.15 Hz) and high (0.15-0.35 Hz) frequency bands (LF and HF, respectively) was determined. Statistically insignificant differences found between exposed and non-exposed groups were found either in time- or in frequency-domain parameters of HRV. No correlation between the power spectrum and the subjects age was noted. Such a relationship, however, could be observed in the control group. In the study group a statistically significant negative correlation was found between the maximum intensity of EM fields and HF power spectrum. Thus it was concluded that occupational exposure to EM fields brings about impairments in the neurovegetative regulation of the cardiovascular function.

Bortkiewicz, A, Zmyslony, M, Gadzicka, E, Palczynski, C, Szmigielski, S, Ambulatory ECG monitoring in workers exposed to electromagnetic fields. J Med Eng Technol 21(2):41-46, 1997.

The aim of this study was to evaluate the function of the circulatory system in workers occupationally exposed to medium frequency electromagnetic fields. The subjects were 71 workers at four AM broadcast stations [0.738-1.503 MHz] aged 20-

68 (mean 46.9 +/- 13.1) years and 22 workers at radio link stations aged 23-67 (mean 48.2 +/- 17.4) years. Workers at AM broadcast stations experienced 2-40 (mean 18.6 +/- 12.1) years' exposure to electromagnetic fields (average daily exposure dose about 115 Vh m-1, maximum exposure levels during shift about 165 V m-1), workers at radio link stations had no history of regular exposure to electromagnetic fields. In all the subjects a general medical examination, resting ECG and 24 h Holter monitoring were performed. The work organization, work period structure, age, lifestyle, nutritional habits and health status in both groups remained fairly similar. The electrocardiographic abnormalities detected in the resting and/ or 24 h ECG were significantly more frequent (p = 0.006) in workers exposed to electromagnetic fields than in non-exposed subjects (75% versus 25%). A clear tendency for a higher number of rhythm disturbances (mostly ExV) was observed in AM broadcast station workers

Bortkiewicz A, Gadzicka E, Szymczak W, Zmyślony M. Heart rate variability (HRV) analysis in radio and TV broadcasting stations workers. Int J Occup Med Environ Health. 25(4):446-455, 2012.

OBJECTIVES: The aim of the study was to assess the mechanism of cardiovascular impairments in workers exposed to UHF-VHF radio frequency electromagnetic fields (EMF). **MATERIALS AND METHODS:** Heart rate variability (HRV) was analysed using 512 normal heart beats registered at rest. The analysis concerned time-domain (STD R-R) and frequency-domain (VLF, LF, HF) parameters of HRV. Fifty nine workers (group I) with low-level and 12 workers (group II) with high-level exposure were examined. The mean age of the subjects was 47 ± 9 years and 41 ± 14 years, and mean exposure duration 19.1 ± 8.8 years and 13 ± 4 years, in groups I and II, respectively. The groups were divided according to: E(max), E(dose), E(mean) for frequencies UHF, VHF and UHF+VHF: The control group consisted of 42 non-exposed subjects, aged 49 ± 8 years. Statistical analysis comprised one-way analysis of variance, covariance analysis and logistic regression models. **RESULTS:** In the exposed groups, the heart rate was higher than in the control one. Standard deviation of R-R intervals (STD R-R) was found to be significantly (p = 0.0285) lower in group I (42.5 ± 24.7 ms) compared to the control group (62.9 ± 53.5 ms). The risk of lowered STD R-R was significantly increased (OR = 2.37, p = 0.023) in group II. Both exposed groups presented significantly higher VLF and LF values than the control group (p = 0.005 and p = 0.0025, respectively). The EMF-exposed groups were characterised by the dominance of the sympathetic system (LF/HF 1.3 ± 0.35). **CONCLUSIONS:** The results indicate that exposure to radiofrequency EMF may affect the neurovegetative regulation.

Boscol P, Di Sciascio MB, D'Ostilio S, Del Signore A, Reale M, Conti P, Bavazzano P, Paganelli R, Di Gioacchino M. Effects of electromagnetic fields produced by radiotelevision broadcasting stations on the immune system of women. Sci Total Environ 273(1-3):1-10, 2001.

The object of this study was to investigate the immune system of 19 women with a mean age of 35 years, for at least 2 years (mean = 13 years) exposed to electromagnetic fields (ELMFs) induced by radiotelevision broadcasting stations in their residential area. In September 1999, the ELMFs (with range 500 KHz-3 GHz) in the balconies of the homes of the women were (mean +/- S.D.) 4.3 +/- 1.4 V/m. Forty-seven women of similar age, smoking habits and atopy composed the control group, with a nearby resident ELMF exposure of < 1.8 V/m. Blood lead and urinary trans-trans muconic acid (a metabolite of benzene), markers of exposure to urban traffic, were higher in the control women. The ELMF exposed group showed a statistically significant reduction of blood NK CD16+-CD56+, cytotoxic CD3(-)-CD8+, B and NK activated CD3(-)-HLA-DR+ and CD3(-)-CD25+ lymphocytes. 'In vitro' production of IL-2 and interferon-gamma (INF-gamma) by peripheral blood mononuclear cells (PBMC) of the ELMF exposed group, incubated either with or without phytohaemoagglutinin (PHA), was significantly lower; the 'in vitro' production of IL-2 was significantly correlated with blood CD16+-CD56+ lymphocytes. The stimulation index (S.I.) of blastogenesis (ratio between cell proliferation with and without PHA) of PBMC of ELMF exposed women was lower than that of the control subjects. The S.I. of blastogenesis of the ELMF exposed group (but not blood NK lymphocytes and the 'in vitro' production of IL-2 and INF-gamma by PBMC) was significantly correlated with the ELMF levels. Blood lead and urinary trans-trans muconic acid were barely correlated with immune parameters: the urinary metabolite of benzene of the control group was only correlated with CD16+-CD56+ cells indicating a slight effect of traffic on the immune system. In conclusion, this study demonstrates that high frequency ELMFs reduce cytotoxic activity in the peripheral blood of women without a dose-response effect.

Braune, S, Wrocklage, C, Raczek, J, Gailus, T, Lucking, CH, Resting blood pressure increase during exposure to a radio-frequency electromagnetic field. Lancet 351(9119):1857-1858, 1998.

Exposure of the right hemisphere to a radiofrequency EMF for 35 min causes in human subjects an increase in sympathetic efferent activity with increases the resting blood pressure between 5-10 mm Hg. The effect is likely caused by vasoconstriction.

Brezitskaia HV, Timchenko OI, [On the mechanism of cytogenetic effect of electromagnetic radiation: a role of oxidation homeostasis]. Radiats Biol Radioecol 40(2):149-153, 2000. [Article in Russian]

It was established in the experiments on rats that the changes in free radical oxidation under the influence of non-ionizing radiation had a wavy character. It was revealed that the changes in oxidation homeostasis preceded development of cytogenetic effects and could be their reason.

Brown HD, Chattopadhyay SK, Ouabain inhibition of kidney ATPase is altered by 9.14 GHz radiation. Bioelectromagnetics 12(3):137-143, 1991.

At each of several stabilized temperatures between 7.0 and 43.8 degrees C, increases in dog-kidney, Na(+)-, K(+)-ATPase catalytic activity were usually observed in association with exposure for 5 min to 9.14 GHz CW microwave radiation in a thin tubular reactor. However, at 24.9 degrees C, a 23% decrease occurred. Comparisons of activity of ouabain-inhibited reactions revealed that the efficacy of the cardiac glycoside as an inhibitor of ATPase activity was severely diminished by the microwave field. The ouabain-site control mechanism may be a specific microwave target at this exposure frequency. Experimental results can be interpreted in terms of molecular structural changes or direct energy input. The estimated SAR of energy that was incident on preparations is 20 W/kg.

Brown DO, Lu ST, Elson EC, Characteristics of microwave evoked body movements in mice. Bioelectromagnetics 15(2):143-161, 1994.

Microwave evoked body movements were studied in mice. A resonant cavity was used to provide head and neck exposure of the mouse to pulsed and gated continuous wave (CW) 1.25 GHz microwaves. No difference in response to pulsed and gated CW stimuli of equal average power was found. The incidence of the microwave evoked body movements increased proportionally with specific absorption (dose) when the whole-body average specific absorption rate was at a constant level (7300 W/kg). Under a constant average specific absorption rate, the response incidence reached a plateau at 0.9 kJ/kg. For doses higher than 0.9 kJ/kg, response incidence was proportional to the specific absorption rate and reached a plateau at 900 W/kg. Body movements could be evoked by a single microwave pulse. The lowest whole-body specific absorption (SA) tested was 0.18 kJ/kg, and the corresponding brain SA was 0.29 kJ/kg. Bulk heating potentials of these SAs were less than 0.1 degree C. For doses higher than 0.9 kJ/kg, the response incidence was also proportional to subcutaneous temperature increment and subcutaneous heating rate. The extrapolated absolute thresholds (0% incidence) were 1.21 degrees C temperature increment and 0.24 degree C/s heating rate. Due to high subcutaneous heating rates, these microwaves must be perceived by the mouse as an intense thermal sensation but not a pain sensation because the temperature increment was well below the threshold for thermal pain. Results of the present study should be considered in promulgation of personnel protection guideline against high peak power but low average power microwaves.

Budinscak V, Goldoni J, Saric M, [Hematologic changes in workers exposed to radio wave radiation]. Arh Hig Rada Toksikol 42(4):367-373, 1991. [Article in Serbo-Croatian (Roman)]

Haematological parameters were measured in 43 radar operators employed in air traffic control occupationally exposed to microwave radiation of low intensity over a period of four years. Exposure to heat, soft X-ray radiation and noise were within maximally allowed limits. The haematological changes included a decreased number of erythrocytes, reticulocytes, platelets, segmented granulocytes and monocytes, and an increased number of leucocytes and lymphocytes. The changes were not pathologically significant and most of them were reversible.

Burlaka A, Selyuk M, Gafurov M, Lukin S, Potaskalova V, Sidorik E. Changes in mitochondrial functioning with electromagnetic radiation of ultra high

frequency as revealed by electron paramagnetic resonance methods. Int J Radiat Biol. 2014 Mar 6. [Epub ahead of print]

Purpose: To study the effects of electromagnetic radiation (EMR) of ultra high frequency (UHF) in the doses equivalent to the maximal permitted energy load for the staffs of the radar stations on the biochemical processes that occur in the cell organelles. Materials and Methods: Liver, cardiac and aorta tissues from the male rats exposed to non-thermal UHF EMR in pulsed and continuous modes were studied during 28 days after the irradiation by the electron paramagnetic resonance (EPR) methods including a spin trapping of superoxide radicals. Results: The qualitative and quantitative disturbances in electron transport chain (ETC) of mitochondria are registered. A formation of the iron-nitrosyl complexes of nitric oxide (NO) radicals with the iron-sulphide (FeS) proteins, the decreased activity of FeS-protein N2 of NADH-ubiquinone oxidoreductase complex and flavo ubisemiquinone growth combined with the increased rates of superoxide production are obtained. Conclusions: (1) Abnormalities in the mitochondrial ETC of liver and aorta cells are more pronounced for animals radiated in a pulsed mode. (2) The alterations in the functioning of the mitochondrial ETC cause increase of superoxide radicals generation rate in all samples, formation of cellular hypoxia, and intensification of the oxide-initiated metabolic changes. (3) Electron paramagnetic resonance methods could be used to track the qualitative and quantitative changes in the mitochondrial ETC caused by the UHF EMR.

Cao G, Liu LM, Cleary SF, Cell cycle alterations induced by isothermal 27 MHz radio-frequency radiation exposure. Bioelectrochem Bioenerg 37(2):131-140, 1995.

The purpose of this study was to test the hypothesis that 27 MHz continuous-wave radio-frequency radiation can alter the mammalian cell cycle in the absence of radiation-induced heating. Relative effects of r.f. radiation on specific phases of the cell cycle were determined by exposing synchronized Chinese hamster ovary (CHO) cells in G_0/G_1 -, S- or G_0/G_1 -phase. The dose-rate dependence of r.f. radiation-induced direct cell-cycle alterations was investigated by exposing CHO cells for 2 h to 5 or 25 W kg^{-1} under isothermal conditions in vitro. Cell cycle alterations were determined by flow cytofluorometric DNA determinations conducted over a period of 4 days after exposure. The DNA distributions of r.f.- or sham-exposed CHO cell samples were compared qualitatively by direct comparison of overlaid and difference distribution. A quantitative measure of the magnitude of the r.f.-induced CHO cell-cycle alterations was obtained by summation of the absolute value of the difference in the number of cells in all regions of the DNA distribution. The precision of the cytoflorometric assay was determined by comparison of DNA distributions of replicate CHO cell samples. The r.f. exposure induced time- and dose-rate-dependent cell cycle alterations. Maximum responses occurred 3 days after exposure at a specific absorption rate (SAR) of 25 W kg^{-1}. Comparison of temporal responses of cells exposed to 5 W kg^{-1} vs. 25 W kg^{-1} indicated an interaction of r.f. exposure intensity with cell cycle phase. In contrast to r.f.-

radiation-induced alterations in the cycles of CHO cells exposed during G_0/G_1 - or S-phase, there were minimal effects on G_2/M -phase CHO cells at either SAR, indicating lessened sensitivity of this cell cycle phase. Whereas G_0/G_1 - or S-phase cells exposed to either SAR approached baseline levels of alteration by 4 days after exposure, there was a statistically significant increased alteration in cells exposed at 25 W kg^{-1} relative to cells exposed at 5 W kg^{-1}. This indicated an r.f.-dose-rate-dependent effect on the duration of cell cycle alterations.

Chemeris NK, Gapeyev AB, Sirota NP, Gudkova OY, Kornienko NV, Tankanag AV, Konovalov IV, Buzoverya ME, Suvorov VG, Logunov VA. DNA damage in frog erythrocytes after in vitro exposure to a high peak-power pulsed electromagnetic field. Mutat Res. 558(1-2):27-34, 2004.

Till the present time, the genotoxic effects of high peak-power pulsed electromagnetic fields (HPPP EMF) on cultured cells have not been studied. We investigated possible genotoxic effects of HPPP EMF (8.8GHz, 180ns pulse width, peak power 65kW, repetition rate 50Hz) on erythrocytes of the frog Xenopus laevis. We used the alkaline comet assay, which is a highly sensitive method to assess DNA single-strand breaks and alkali-labile lesions. Blood samples were exposed to HPPP EMF for 40min in rectangular wave guide. The specific absorption rate (SAR) calculated from temperature kinetics was about 1.6kW/kg (peak SAR was about 300MW/kg). The temperature rise in the blood samples at steady state was [Formula: see text] degrees C. The data show that the increase in DNA damage after exposure of erythrocytes to HPPP EMF was induced by the rise in temperature in the exposed cell suspension. This was confirmed in experiments in which cells were incubated for 40min under the corresponding temperature conditions. The results allow us to conclude that HPPP EMF-exposure at the given modality did not cause any a-thermal genotoxic effect on frog erythrocytes in vitro.

Clark ML, Burch JB, Yost MG, Zhai Y, Bachand AM, Fitzpatrick CT, Ramaprasad J, Cragin LA, Reif JS. Biomonitoring of estrogen and melatonin metabolites among women residing near radio and television broadcasting transmitters.J Occup Environ Med. 49(10):1149-1156, 2007.

OBJECTIVES: Metabolites of estrogen (estrone-3-glucuronide [E1G]) and melatonin (6-hydroxymelatonin sulfate [6-OHMS]) were characterized among women living in a community with increased radiofrequency (RF) exposure from radio and television transmitters. **METHODS:** RF spot measurements, and personal 60-Hz magnetic field and residential parameters were collected. Overnight urine samples were assayed for E1G and 6-OHMS excretion. **RESULTS:** Among premenopausal women, there were no associations between RF or 60-Hz nonionizing radiation and E1G or 6-OHMS excretion. Among postmenopausal women, increased residential RF exposures, transmitter proximity and visibility, and temporally stable 60-Hz exposures were significantly associated with increased E1G excretion. This association was strongest among postmenopausal women with low overnight 6-OHMS levels. **CONCLUSIONS:** RF and temporally stable 60-Hz exposures were associated with increased E1G excretion among postmenopausal women. Women with reduced nocturnal 6-OHMS excretion may represent a sensitive subgroup.

Dimbylow P, Khalid M, Mann S. Assessment of specific energy absorption rate (SAR) in the head from a TETRA handset. Phys Med Biol. 48(23):3911-26, 2003.

Finite-difference time-domain (FDTD) calculations of the specific energy absorption rate (SAR) from a representative TETRA handset have been performed in an anatomically realistic model of the head. TETRA (Terrestrial Trunked Radio) is a modern digital private mobile radio system designed to meet the requirements of professional users, such as the police and fire brigade. The current frequency allocations in the UK are 380-385 MHz and 390-395 MHz for the public sector network. A comprehensive set of calculations of SAR in the head was performed for positions of the handset in front of the face and at both sides of the head. The representative TETRA handset considered. operating at 1 W in normal use, will show compliance with both the ICNIRP occupational and public exposure restrictions. The handset with a monopole antenna operating at 3 W in normal use will show compliance with both the ICNIRP occupational and public exposure restrictions. The handset with a helical antenna operating at 3 W in normal use will show compliance with the ICNIRP occupational exposure restriction but will be over the public exposure restriction by up to approximately 50% if kept in the position of maximum SAR for 6 min continuously.

Dmoch A, Moszczynski P, [Levels of immunoglobulin and subpopulations of T lymphocytes and NK cells in men occupationally exposed to microwave radiation in frequencies of 6-12 GHz]. Med Pr 49(1):45-49, 1998. [Article in Polish]

Immunoglobulin concentrations and T-lymphocyte subsets in workers of TV re-transmission and satellite communication centres were assessed. An increase in IgG and IgA concentrations, an increased count of lymphocytes and T8 lymphocytes, an decreased count of NK cells and a lower value of T-helper/T-suppressor ratio were found. Neither disorders in immunoglobulin concentrations nor in the count of T8 and NK cells had any clinical implications.

Dolk H, Shaddick G, Walls P, Grundy C, Thakrar B, Kleinschmidt I, Elliott P, Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter. Am J Epidemiol 145(1):1-9, 1997.

A small area study of cancer incidence in 1974-1986 was carried out to investigate an unconfirmed report of a "cluster" of leukemias and lymphomas near the Sutton Coldfield television (TV) and frequency modulation (FM) radio transmitter in the West Midlands, England. The study used a national database of postcoded cancer registrations, and population and socioeconomic data from the 1981 census. Selected cancers were hematopoietic and lymphatic, brain, skin, eye, male breast, female breast, lung, colorectal, stomach, prostate, and bladder. Expected numbers of cancers in small areas were calculated by indirect standardization, with stratification for a small area socioeconomic index. The study area was defined as a 10 km radius circle around the transmitter, within which 10 bands of increasing distance from the transmitter were defined as a basis for testing for a decline in risk with distance, and an inner area was arbitrarily defined for descriptive purposes as a 2 km radius circle. The risk of adult leukemia within 2 km was 1.83 (95% confidence interval 1.22-2.74), and there was a significant decline in risk with distance from the transmitter (p = 0.001). These findings appeared to be consistent over the periods 1974-1980, 1981-1986, and were probably largely independent of the initially reported cluster, which appeared to concern mainly a later period. In the context of variability of leukemia risk across census wards in the West Midlands as a whole, the Sutton Coldfield findings were unusual. A significant decline in risk with distance was also found for skin cancer, possibly related to residual socioeconomic confounding, and for bladder cancer. Study of other radio and TV transmitters in Great Britain is required to put the present results in wider context. No causal implications can be made from a single cluster investigation of this kind.

Dutta SK, Verma M, Blackman CF, Frequency-dependent alterations in enolase activity in Escherichia coli caused by exposure to electric and magnetic fields. Bioelectromagnetics 15(5):377-383, 1994.

Some neurochemical effects of low-intensity electric and magnetic fields have been shown to be nonlinear functions of exposure parameters. These effects occurred within narrow ranges of frequency and intensity. Previous studies on membrane-associated endpoints in cell culture preparations demonstrated changes in calcium efflux and in acetylcholinesterase activity following exposure to radiofrequency radiation, amplitude modulated (AM) at 16 and at 60 Hz, at a specific absorption rate of 0.05 W/kg. In this study, these modulation frequencies were tested for their influence on the activity of a cytoplasmic enzyme, enolase, which is being tested clinically for detection of neoplasia. Escherichia coli cultures containing a plasmid with a mammalian gene for enolase were exposed for 30 min, and cell extracts were assayed for enolase activity by measuring absorbance at 240 nm. The enolase activity in exposed cultures was compared to the activity in paired control cultures. Exposure to 147 MHz carrier waves at 0.05 W/kg, AM at 16 Hz showed enolase activity enhanced by 62%, and AM at 60 Hz showed enolase activity reduced by 28%. Similarly, exposure to 16 Hz fields alone, at 21.2 V/mrms (electric) and 97 nTrms (magnetic), showed enhancement in enolase activity by 59%, whereas exposure to 60 Hz fields alone, at 14.1 V/mrms (electric) and 65 nTrms (magnetic), showed reduction in activity by 24%. Sham exposures as well as exposure to continuous-wave 147 MHz radiation at 0.05 W/kg showed no change in enolase activity.

Ellingsrud S, Johnsson A, Perturbations of plant leaflet rhythms caused by electromagnetic radio-frequency radiation. Bioelectromagnetics 14(3):257-271, 1993.

The minute-range up and down rhythms of the lateral leaflets of Desmodium gyrans has been studied when exposed to electromagnetic radiation in the radio-frequency (RF) range. The RF radiation was applied as homogeneous 27.12

MHz fields in specially-designed exposure cells (and in some cases as non-homogeneous radiation of 27 MHz, amplitude modulated by 50 Hz, in front of commercial diathermy equipment). All fields were applied as pulses. We report effects in the leaflet rhythms such as temporary changes in the amplitude, period, and phase. The radiation could also cause temporary or complete cessations of the rhythms. The lowest dose (8 W/cm2) used was still effective.

English NJ, Mooney DA. Denaturation of hen egg white lysozyme in electromagnetic fields: A molecular dynamics study. J Chem Phys. 126(9):091105, 2007.

Nonequilibrium molecular dynamics simulations of hen egg white lysozyme have been performed in the canonical ensemble at 298 K in the presence of external electromagnetic fields of varying intensity in the microwave to far-infrared frequency range. Significant nonthermal field effects were noted, such as marked changes in the protein's secondary structure which led to accelerated incipient local denaturation relative to zero-field conditions. This occurred primarily as a consequence of alignment of the protein's total dipole moment with the external field, although the enhanced molecular mobility and dipolar alignment of water molecules is influential on sidechain motion in solvent-exposed regions. The applied field intensity was found to be highly influential on the extent of denaturation in the frequency range studied, and 0.25-0.5 V A(rms) (-1) fields were found to induce initial denaturation to a comparable extent to thermal denaturation in the 400 to 500 K range. In subsequent zero-field simulations following exposure to the e/m field, the extent of perturbation from the native fold and the degree of residual dipolar alignment were found to be influential on incipient folding.

Enin LD, Akoev GN, Potekhina IL, Oleiner VD, [Effect of extremely high-frequency electromagnetic radiation on the function of skin sensory endings]. Patol Fiziol Eksp Ter Sep-Dec;(5-6):23-25, 1992. [Article in Russian]

The specific features of skin receptor function on the sole of the hind limb of an albino rat were studied in an acute experiment. Impulse activity recorded from the solitary fibres of the tibial nerve showed that receptor units (RU) responded to mechanical stimulation of the skin. Irradiation of the skin surface by low-intensity millimeter band electromagnetic field (frequencies of 55.61 and 73 GHz) in the zone of the RU led to diminution of RU sensitivity to the mechanical stimulus. One half of the RU ceased to respond to the mechanical stimulation 25 minutes after irradiation. The other half continued responding to stimulation even after 35 minutes of irradiation, but the character of the RU response was significantly changed. A strict frequency-resonance dependence of the biological effects was revealed. It is concluded that electromagnetic radiation has a modulatory-inhibiting effect on the skin RU. The authors suggest a possible mechanism of realization of the effect of electromagnetic radiation of extremely high-frequencies and low power on the skin receptor function

Espinosa JM, Liberti M, Lagroye I, Veyret B. Exposure to AC and DC magnetic

fields induces changes in 5-HT1B receptor binding parameters in rat brain membranes. Bioelectromagnetics. 27(5):414-422, 2006.

The binding properties of the G-protein coupled receptor (GPCR) serotonin 5-HT1B receptor were studied under exposure to AC (50 and 400 Hz) and DC magnetic fields (MF) in rat brain membranes. This was an attempt at replicating the positive findings of Massot et al. In saturation experiments using [3H]5-HT, 1-h exposures at 1.1 mT(rms) 50 Hz caused statistically significant increases in both the K(D) and B(max) binding parameters, from 1.74 +/- 0.3 to 4.51 +/- 0.86 nM and from 1428 +/- 205 to 2137 +/- 399 CPM, respectively, in good agreement with previous results. Exposure of the membranes at 400 Hz 0.675 mT(rms) did not elicit a larger increase in K(D) in spite of a much larger induced current density. DC fields (1.1 and 11 mT) had a lesser effect compared to AC fields at low values of K(Dsham), but decreased the affinity at higher values of K(Dsham). Modeling of the receptor-ligand-G protein interactions using the extended ternary complex model yielded good fits for all our data and that of Massot et al., showing that the AC field may act by decreasing the ability of the G-protein to alter the ligand-receptor affinity. The hypothesis is that the bipolar nature of the AC field explains the different nature of the effects observed with AC and DC exposures. These findings constitute one of the few documented pieces of evidence for cell-free effects of DC and extremely low frequency (ELF) AC MFs in the mT range.

Fabbro-Peray P, Daures JP, Rossi JF. Environmental risk factors for non-Hodgkin's lymphoma: a population-based case-control study in Languedoc-Roussillon, France. Cancer Causes Control 12(3):201-212, 2001.

OBJECTIVE: To investigate the occupational and environmental risk factors related to non-Hodgkin's lymphoma (NHL). METHODS: A case-control study was performed during the 1992-1996 period in Languedoc-Roussillon, southern France. Four hundred and forty-five cases of histologically diagnosed NHL were declared. One thousand and twenty-five randomly selected population controls were interviewed about their medical histories; occupational exposures, such as chemicals, pesticides, and electromagnetic radiation; and toxic habits. RESULTS: The following factors were independently and significantly related to NHL as a result of the multivariate analysis: a previous hematopoietic malignancy (ORa = 11.5, 95% CI 2.4-55.4), a history of hives (ORa = 1.7, 95% CI 1.2-2.2), benzene exposure > 810 days (ORa = 4.6, 95% CI 1.1-19.2), daily welding (ORa = 2.5, 95% CI 1.2-5.0), and activity of radio operator (ORa = 3.1, 95% CI 1.4-6.6). To be an agricultural professional seemed slightly related to NHL in reference to non-professionals (ORa = 1.5, 95% CI 1.0-2.1). All of these results have also been adjusted for age, gender, education level, and urban setting. CONCLUSIONS: As some of the reported associations were based on a very small proportion of exposed subjects, further investigations are necessary to confirm our results. However, the findings suggest that factors related to altered immune functions such as a history of hematopoietic malignancy, history of hives, occupational exposure to benzene, or being an agricultural professional might increase the risk of NHL. Currently, underlying mechanisms for these associations are still unclear, and further investigations focused on interactions between immunity alterations and different chemicals would be of great interest.

Fesenko EE, Geletyuk VI, Kazachenko VN, Chemeris NK Preliminary microwave irradiation of water solutions changes their channel-modifying activity. FEBS Lett 366(1):49-52, 1995.

Earlier we have shown that millimetre microwaves (42.25 GHz) of non-thermal power, upon direct admittance into an experiment bath, greatly influence activation characteristics of single Ca(2+)-dependent K+ channels (in particular, the channel open state probability, Po). Here we present new data showing that similar changes in Po arise due to the substitution of a control bath solution for a preliminary microwave irradiated one of the same composition (100 mmol/l KCl with Ca2+ added), with irradiation time being 20-30 min. Therefore, due to the exposure to the field the solution acquires some new properties that are important for the channel activity. The irradiation terminated, the solution retains a new state for at least 10-20 min (solution memory). The data suggest that the effects of the field on the channels are mediated, at least partially, by changes in the solution properties.

Fesenko EE, Novoselova EG, Semiletova NV, Agafonova TA, Sadovnikov VB, [Stimulation of murine natural killer cells by weak electromagnetic waves in the centimeter range]. Biofizika 44(4):737-741, 1999. [Article in Russian]

Irradiation with electromagnetic waves (8.15-18 GHz, 1 Hz within, 1 microW/cm2) in vivo increases the cytotoxic activity of natural killer cells of rat spleen. In mice exposed for 24-72 h, the activity of natural killer cells increased by 130-150%, the increased level of activity persisting within 24 h after the cessation of treatment. Microwave irradiation of animals in vivo for 3.5 and 5 h, and a short exposure of splenic cells in vitro did not affect the activity of natural killer cells.

Fesenko, EE, Makar, VR, Novoselova, EG, Sadovnikov, VB, Microwaves and cellular immunity. I. Effect of whole body microwave irradiation on tumor necrosis factor production in mouse cells. Bioelectrochem Bioenerg 49(1):29-35, 1999.

Whole body microwave sinusoidal irradiation of male NMRI mice with 8.15-18 GHz (1 Hz within) at a power density of 1 microW/cm2 caused a significant enhancement of TNF production in peritoneal macrophages and splenic T lymphocytes. Microwave radiation affected T cells, facilitating their capacity to proliferate in response to mitogenic stimulation. The exposure duration necessary for the stimulation of cellular immunity ranged from 5 h to 3 days. Chronic irradiation of mice for 7 days produced the decreasing of TNF production in peritoneal macrophages. The exposure of mice for 24 h increased the TNF production and immune proliferative response, and these stimulatory effects persisted over 3 days after the termination of exposure. Microwave treatment increased the endogenously produced TNF more effectively than did lipopolysaccharide, one of the most potential stimuli of synthesis of this cytokine.

The role of microwaves as a factor interfering with the process of cell immunity is discussed.

Gadzicka E, Bortkiewicz A, Zmyslony M, Palczynski C, [Evaluation of selected functional circulation parameters of workers from various occupational groups exposed to electromagnetic fields of high frequency. III. 24-h monitoring of arterial blood pressure]. Med Pr 48(1):15-24, 1997. [Article in Polish]

The problem of blood pressure regulation in persons occupationally exposed to electromagnetic fields (EMF) has not as yet been elucidated, and most data come from studies carried out long time ago (1960-70) in the former Soviet Union. Our study was aimed at verifying the Soviet data by means of modern methods. Together with traditional methods, a 24-h monitoring of arterial blood pressure (ABP) using a Medilog ABP kit (Oxford) were employed. Measurements were taken automatically every 0.5 h during daily activities and every 1 h during the night rest (about 41 measurements/day). The mean systolic and diastolic blood pressure and heart rate were calculated over day (BPSDOver, BPDOver, HROver), during daily activities (HPDD, BPSD, HRD) and during the night rest (BPSN, BPDN, HRN). The subjective and objective examinations were carried out as well as resting ECG and a 24-h Holter were performed (the results have been published earlier). The study covered male workers of middlewave broadcast stations (71), radioservice (40) and radio line stations (42). The subjects were aged 21-60 years and the duration of their work with devices generating high frequency EMF ranged between 1 and 42 years. The first group of workers was exposed to EFM at the frequency of 1 Mhz, the second at about 150 Mhz and the third group, not exposed, served as the control group. The study revealed that the mean arterial blood pressure and the day/night blood pressure variability indicator showed no significant differences between the groups, whereas the daily heart rate was significantly lower in the workers of middlewave broadcast stations in comparison with the controls despite similar type of work as far as physical effort and psychic burden are concerned, and similar non-occupational activities. The day/night heart rate variability indicator was significantly lower in the groups exposed. The decreased value of this indicator may suggest the occurrence of disorders in the neurovegetative regulation. In persons employed at radioservice stations a higher incidence of the increased arterial blood pressure, in comparison with the control group, was observed.

Galat VV, Mezhevikina LM, Zubin MN, Lepikhov KA, Khramov RN, Chailakhian LM, [Effect of millimeter waves on the early development of the mouse and sea urchin embryo]. Biofizika 44(1):137-140, 1999. [Article in Russian]

The action of nonthermal electromagnetic radiation (EMR) of the millimeter range on the early development of murine and sea urchin embryos was investigated. An MRTA-01E-03 generator with a frequency of 54-78 GHz and radiation intensity of

0.06 mWt/cm2 was used. The embryos were irradiated during 30 min at the stage of two blastomeres. The number of murine embryos that reached the blastocyst stage increased (up to 97.3% in comparison with 87.5% in control). The total time of cultivation up to the blastocyst stage was also shorter (72 h) than in control (96 h). The irradiation had effect on the development of sea urchin embryos only if embryos with a weakened viability were tested. The results indicate that millimeter electromagnetic radiation has a stimulating effect on the early development of embryos, increasing the resistance of embryos to unfavorable environmental conditions.

Gao XF,Pei LP, Chen CH, Yang XS, Zhang GB, Deng ZH, Yu ZP. [Effects of occupational microwave irradiation on heat shock protein 70 expressions in rat hippocampus.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):553-556, 2009. [Article in Chinese]

OBJECTIVE: To study the change of heat shock protein (HSP)70 expression after exposure to occupational microwave in rats hippocampus, and explore the role of HSP70 in the mechanism of bio-effect of microwave irradiation. METHODS: The animal model was established by whole body exposures in 90, 5 W/cm(2) microwave irradiation field for 20 min in rats. Changes of the mRNA of hsp70 expressions in rat hippocampus at different time were studied by RT-PCR, and the protein change by Western blot. RESULTS: The mRNA and protein expression of hsp70 in rat hippocampus increased after 90 W/cm(2) and 5 W/cm(2) microwave irradiation for 20 min. The anal temperature and the value of SAR increased significantly. These changes were positively correlated with power and irradiation time of microwave. The results indicated that microwave irradiation led to HSP70 syntheses effectively. CONCLUSION: Microwave irradiation can obviously induce the thermal effect and activate HSP70, and initiate the endogens protective mechanism of central nervous system.

Gao XF, Wang SM, Peng RY, Wang LF, Zuo HY, Gao YB, Dong Q, Dong B. [Effect of microwave radiation on primary cultured Sertoli cells.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):530-533, 2009. [Article in Chinese]

OBJECTIVE: To explore whether microwave radiation may cause injury of primary cultured Sertoli cells. METHODS: The model of primary cultured Sertoli cells in vitro was established, which was radiated by microwave with average power density 0, 30 and 100 mW/cm(2) for five minutes. The changes of cell cycle, apoptosis and death, and intracellular Ca2+ concentration in the Sertoli cells were measured at sixth hours through Annexin V-PI double labeling and Fluo-3-AM labeling, flow cytometry combined with laser scanning confocal microscopy after microwave exposure. RESULTS: The numbers of Sertoli cells were obviously reduced in G0-G1 and G2-M phase (62.57% +/- 3.22% and 8.25% +/- 1.75%) and increased in S phase (29.17% +/- 4.87%) compared with the control groups (79.18% +/- 0.24%, 11.17% +/- 0.50% and 9.64% +/- 0.62%) ($P < 0.05$ or $P < 0.01$), but the changes of rate of apoptosis and death and intracellular Ca2+ concentration showed no difference at 6 h after exposure to 30 mW/cm(2) microwave. There was a significant increase in the Sertoli cell counts of G0-G1 phase (87.69% +/- 1.32%), and decrese in the Sertoli cell counts of G2-M and S phase (7.41% +/- 0.60% and 4.87% +/- 0.91%) (P < 0.01). There was also a significant increase in intracellular Ca2+ concentration and rate of apoptosis and death (P < 0.05 or P < 0.01) at 6 h after exposure to 100 mW/cm(2) microwave. CONCLUSION: 100 mW/cm(2) microwave radiation may cause growth inhibition and increase of apoptosis and death in the primary cultured Sertoli cells. The increase of intracellular Ca2+ concentration is one of the injury mechanisms.

Gapeev AB, Lakushina VS, Chemeris NK, Fesenko EE [Modulated extremely high frequency electromagnetic radiation of low intensity activates or inhibits respiratory burst in neutrophils depending on modulation frequency]. Biofizika 42(5):1125-1134, 1997. [Article in Russian]

The influence of low-intensity modulated electromagnetic radiation of extremely high frequencies (EHF EMR) on synergistic reaction of calcium ionophore A23187 and phorbol ester PMA in activation of the respiratory burst of the peritoneal neutrophils of mice line NMRI was investigated. The production of reactive oxygen species by the neutrophils was estimated by luminol-dependent chemiluminescence technique. The cells were irradiated in the far field zone of the channel radiator for 20 min in the presence of A23187 and then were activated by PMA after switching off the irradiation. It was shown, that continuous EHF EMR (50 microW/cm2) inhibited quasi-resonantly the synergistic reaction. The maximum effect was about 25% at carrier frequency of 41.95 GHz. Modulated radiation with carrier frequency of 41.95 GHz and modulation frequency of 1 Hz activated the synergistic reaction, but at modulation frequencies of 0.1, 16 and 50 Hz inhibited one. At fixed modulation frequency of 1 Hz the nonlinear dependence of the effect on the carrier frequency was found. The synergistic reaction was activated in the frequency range of 41.95-42.05 GHz and was inhibited at the frequencies of 41.8-41.9 GHz. The effect was observed only at raised intracellular free calcium concentration and at calcium fluxes through plasma membrane. The obtained results prove the possibility of control over cell functioning by low-intensity modulated EHF EMR, presumably, manipulating by connected systems of enzyme reactions.

Gapeev AB, Chemeris NK, [Modeling of the effect of modulated electromagnetic radiation on animal cells]. Biofizika 45(2):299-312, 2000.

Frequency-dependent modifications of intracellular free calcium concentration ([Ca2+]i) in neutrophils exposures to modulated extremely high frequency electromagnetic radiation were analyzed using a special mathematical model for [Ca2+]i oscillations. The model took into account the activation of Ca2+ influx into the cell by cytosolic Ca2+ and Ca(2+)-induced Ca2+ release from intracellular stores. The calcium channels of plasma membrane were chosen as a target for the influence of harmonic signal and additive noise in the model. The model simulation showed that in response to modulating signal, the rise in [Ca2+]i, has frequency dependence and phase dependence in relation to the moment of chemical stimulation. The phase-frequency dependence of the effect was observed at a certain sequence of delivery of chemical stimulus and modulating signal to the cell. At intensities of modulating signals exceeding the threshold, a rise in [Ca2+]i, reaching a level of more than 50% of the initial level, was observed at a frequency of about 1 Hz and in the phase range of 0.3-2.5 radians. The effect was found only at high intensities of chemical stimulus. The additive noise introduced into the system modified qualitatively and quantitatively the phase-frequency characteristics of the cell response to the modulating signal. An increase in noise intensity resulted in a displacement of the average frequency of the band of rise in [Ca2+]i, and then the emergence of a set of bands with a greater Q-factors. The analysis of dynamics of the nonlinear system in terms of the stability theory showed that, as the intensity of chemical stimulus increases, the system transits by means of a series of bifurcations from regular driving to chaotic, and then to oscillations, induced by a modulating harmonic signal. The boundary of the transition of oscillations from chaotic to induced ones corresponds to a specific "threshold" of the intensity of chemical stimulus for the significant rise in [Ca2+]i in response to the modulating signal. The results of the model analysis are in good correspondence with the experimental data obtained earlier, namely, with the effects of modulated extremely high-frequency electromagnetic radiation on neutrophils, which were observed only in the presence of Ca2+ in extracellular medium and at high concentrations of calcium ionophore A23187. Thus, as the characteristic frequency of the quasi-periodic process of calcium signalling in the cell coincides with the frequency of external field, a narrow-band rise in [Ca2+]i is observed, which can result in a modification of the functional activity of the cell.

Gapeev AB, Lushnikov KV, Shumilina IuV, Sirota NP, Sadovnikov VB, Chemeris NK. [Effects of low-intensity extremely high frequency electromagnetic radiation on chromatin structure of lymphoid cells in vivo and in vitro] Radiats Biol Radioecol 43(1):87-92, 2003. [Article in Russian]

Using a comet assay technique, it was shown for the first time that low-intensity extremely high-frequency electromagnetic radiation (EHF EMR) in vivo causes oppositely directed effects on spatial organization of chromatin in cells of lymphoid organs. In 3 hrs after single whole-body exposure of NMRI mice for 20 min at 42.0 GHz and 0.15 mW/cm2, an increase by 16% ($p < 0.03$ as compared with control) and a decrease by 16% ($p < 0.001$) in fluorescence intensity of nucleoids stained with ethidium bromide were found in thymocytes and splenocytes, respectively. The fluorescence intensity of stained nucleoids in peripheral blood leukocytes was not changed after the exposure. The exposure of cells of Raji hunan lymphoid line and peripheral blood leukocytes to the EHF EMR in vitro induced a decrease in fluorescence intensity by 23% ($p < 0.001$) and 18% ($p < 0.05$), respectively. These effects can be determined by changes in a number of physiological alkali-labile sites in DNA of exposed cells. We suggested that the effects of low-intensity EHF EMR on the immune system cells are realized with the participation of neuroendocrine and central nervous systems.

Gapeyev AB, Kulagina TP, Aripovsky AV. Exposure of tumor-bearing mice to extremely high-frequency electromagnetic radiation modifies the composition

of fatty acids in thymocytes and tumor tissue. Int J Radiat Biol. 89(8):602-610, 2013.

Purpose: To test the participation of fatty acids (FA) in antitumor effects of extremely high-frequency electromagnetic radiation (EHF EMR), the changes in the FA composition in the thymus, liver, blood plasma, muscle tissue, and tumor tissue in mice with Ehrlich solid carcinoma exposed to EHF EMR were studied. Materials and methods: Normal and tumor-bearing mice were exposed to EHF EMR with effective parameters (42.2 GHz, 0.1 mW/cm^2, 20 min daily during five consecutive days beginning the first day after the inoculation of tumor cells). Fatty acid composition of various organs and tissues of mice were determined using a gas chromatography. Results: It was shown that the exposure of normal mice to EHF EMR or tumor growth significantly increased the content of monounsaturated FA (MUFA) and decreased the content of polyunsaturated FA (PUFA) in all tissues examined. Exposure of tumor-bearing mice to EHF EMR led to the recovery of FA composition in thymocytes to the state that is typical for normal animals. In other tissues of tumor-bearing mice, the exposure to EHF EMR did not induce considerable changes that would be significantly distinguished between disturbances caused by EHF EMR exposure or tumor growth separately. In tumor tissue which is characterized by elevated level of MUFA, the exposure to EHF EMR significantly decreased the summary content of MUFA and increased the summary content of PUFA. Conclusions: The recovery of the FA composition in thymocytes and the modification of the FA composition in the tumor under the influence of EHF EMR on tumor-bearing animals may have crucial importance for elucidating the mechanisms of antitumor effects of the electromagnetic radiation.

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EMR did not induce considerable changes that would be significantly distinguished between disturbances caused by EHF EMR exposure or tumor growth separately. In tumor tissue which is characterized by elevated level of MUFA, the exposure to EHF EMR significantly decreased the summary content of MUFA and increased the summary content of PUFA. Conclusions: The recovery of the FA composition in thymocytes and the modification of the FA composition in the tumor under the influence of EHF EMR on tumor-bearing animals may have crucial importance for elucidating the mechanisms of antitumor effects of the electromagnetic radiation.

Garaj-Vrhovac V, Horvat D, Koren Z, The effect of microwave radiation on the cell genome. Mutat Res 243(2):87-93, 1990.

Cultured V79 Chinese hamster cells were exposed to continuous radiation, frequency 7.7 GHz, power density 30 mW/cm2 for 15, 30, and 60 min. The parameters investigated were the incorporation of [3H]thymidine and the frequency of chromosome aberrations. Data obtained by 2 methods (the incorporation of [3H]thymidine into DNA and autoradiography) showed that the inhibition of [3H]thymidine incorporation took place by complete prevention of DNA from entering into the S phase. The normal rate of incorporation of [3H]thymidine was recovered within 1 generation cycle of V79 cells. Mutagenic tests performed concurrently showed that even DNA macromolecules were involved in the process. In comparison with the control samples there was a higher frequency of specific chromosome lesions in cells that had been irradiated. Results discussed in this study suggest that microwave radiation causes changes in the synthesis as well as in the structure of DNA molecules.

Garaj-Vrhovac V, Horvat D, Koren Z, The relationship between colony-forming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese hamster cells exposed to microwave radiation. Mutat Res 263(3):143-149, 1991.

Cultured V79 Chinese hamster fibroblast cells were exposed to continuous radiation, frequency 7.7 GHz, power density 0.5 mW/cm2 for 15, 30 and 60 min. The effect of microwave radiation on cell survival and on the incidence and frequency of micronuclei and structural chromosome aberrations was investigated. The decrease in the number of irradiated V79 cell colonies was related to the power density applied and to the time of exposure. In comparison with the control samples there was a significantly higher frequency of specific chromosome aberrations such as dicentric and ring chromosomes in irradiated cells. The presence of micronuclei in irradiated cells confirmed the changes that had occurred in chromosome structure. These results suggest that microwave radiation can induce damage in the structure of chromosomal DNA.

Garaj-Vrhovac V, Fucic A, Horvat D, The correlation between the frequency of micronuclei and specific chromosome aberrations in human lymphocytes exposed to microwave radiation in vitro. Mutat Res 281(3):181-186, 1992.

Human whole-blood samples were exposed to continuous microwave radiation, frequency 7.7 GHz, power density 0.5, 10 and 30 mW/cm2 for 10, 30 and 60 min. A correlation between specific chromosomal aberrations and the incidence of micronuclei after in vitro exposure was observed. In all experimental conditions, the frequency of all types of chromosomal aberrations was significantly higher than in the control samples. In the irradiated samples the presence of dicentric and ring chromosomes was established. The incidence of micronuclei was also higher in the exposed samples. The results of the structural chromosome aberration test and of the micronucleus test were comparatively analyzed. The values obtained showed a positive correlation between micronuclei and specific chromosomal aberrations (acentric fragments and dicentric chromosomes). The results of the study indicate that microwave radiation causes changes in the genome of somatic human cells and that the applied tests are equally sensitive for the detection of the genotoxicity of microwaves.

Garaj-Vrhovac V, Gajski G, Pažanin S, Sarolić A, Domijan AM, Flajs D, Peraica M. Assessment of cytogenetic damage and oxidative stress in personnel occupationally exposed to the pulsed microwave radiation of marine radar equipment. Int J Hyg Environ Health. 4(1):59-65, 2011.

Due to increased usage of microwave radiation, there are concerns of its adverse effect in today's society. Keeping this in view, study was aimed at workers occupationally exposed to pulsed microwave radiation, originating from marine radars. Electromagnetic field strength was measured at assigned marine radar frequencies (3 GHz, 5.5 GHz and 9.4 GHz) and corresponding specific absorption rate values were determined. Parameters of the comet assay and micronucleus test were studied both in the exposed workers and in corresponding unexposed subjects. Differences between mean tail intensity (0.67 vs. 1.22) and moment (0.08 vs. 0.16) as comet assay parameters and micronucleus test parameters (micronuclei, nucleoplasmic bridges and nuclear buds) were statistically significant between the two examined groups, suggesting that cytogenetic alterations occurred after microwave exposure. Concentrations of glutathione and malondialdehyde were measured spectrophotometrically and using high performance liquid chromatography. The glutathione concentration in exposed group was significantly lower than in controls (1.24 vs. 0.53) whereas the concentration of malondialdehyde was significantly higher (1.74 vs. 3.17), indicating oxidative stress. Results suggests that pulsed microwaves from working environment can be the cause of genetic and cell alterations and that oxidative stress can be one of the possible mechanisms of DNA and cell damage.

Geletyuk VI, Kazachenko VN, Chemeris NK, Fesenko EE, Dual effects of microwaves on single Ca(2+)-activated K+ channels in cultured kidney cells Vero. FEBS Lett 359(1):85-88, 1995.

Using the patch voltage-clamp method, possible effects of millimetre microwaves

(42.25 GHz) on single Ca(2+)-activated K+ channels in cultured kidney cells (Vero) were investigated. It was found that exposure to the field of non-thermal power (about 100 microW/cm2) for 20-30 min greatly modifies both the Hill coefficient and an apparent affinity of the channels for Ca2+(i). The data suggest that the field alters both cooperativity and binding characteristics of the channel activation by internal Ca2+. The effects depend on initial sensitivity of the channels to Ca2+ and the Ca2+ concentration applied.

Goldoni J, Hematological changes in peripheral blood of workers occupationally exposed to microwave radiation. Health Physics 58:205-207, 1990.

In a group of 14 men occupationally exposed to microwaves, hematological examinations were performed at an interval of 2 years. The exposed group consisted of male radar technicians working in air traffic control. They were exposed to pulsed microwaves of various frequencies within the whole range used in radar operations for 7-14 years. Controls were 10 male electronic technicians working at the airport, but far from any sources of microwave radiation. The results of hematological examinations at a 2-year interval in the exposed group show a significant decrease in thrombocyte and leukocyte counts. The number of leukocytes and erythrocytes in the peripheral blood was significantly lower in the exposed than in the control group. There was no significant difference in reticulocyte and lymphocyte counts.

Goldoni J, Durek M, Koren Z, Health status of personnel occupationally exposed to radiowaves. Arh Hig Rada Toksikol 44(3):223-228, 1993.

The findings of medical examinations performed in two groups of persons occupationally exposed to microwaves and radiofrequency radiation are presented in comparison with control findings. A group of 49 radar operators from the Zagreb Air Traffic Control was examined twice within a period of 18 months. The other group comprised 46 workers employed in radio relay stations. The control group were 46 workers from the Zagreb Airport. A follow-up study showed significant changes in haematological and biochemical parameters, in electrical brain activity and in capillaroscopic and ophthalmological findings in the group of radar operators within the followed period. For that group a cross-sectional study of the differences in general health status also showed the highest rate of changes. The results indicate that long-term occupational exposure to microwaves and radiofrequencies may damage sensitive organic systems.

Grajewski B, Cox C, Schrader SM, Murray WE, Edwards RM, Turner TW, Smith JM, Shekar SS, Evenson DP, Simon SD, Conover DL, Semen quality and hormone levels among radiofrequency heater operators. J Occup Environ Med42(10):993-1005, 2000.

Approximately 9,000,000 US workers are occupationally exposed to radiogrequency (RF) radiation; over 250,000 operate RF dielectric heaters. Our purpose was to determine whether male RF heater operators experience increased adverse reproductive effects reflected in reduced semen quality or altered hormone levels. We measured incident RF heater radiation exposures and RF-induced foot currents at four companies. For 12 male heater operators and a comparison group of 34 RF-unexposed men, we measured 33 parameters of semen quality and four serum hormones. Despite wide variation in individual exposure levels, near field strengths and induced foot currents did not exceed current standard levels and guidelines. We observed minor semen quality and hormonal differences between the groups, including a slightly higher mean follicle-stimulating hormone level for exposed operators (7.6 vs 5.8 mIU/mL). Further occupational studies of RF-exposed men may be warranted.

Grayson JK, Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study. Am J Epidemiol 143(5):480-486, 1996.

A nested case-control study was used to investigate the relation between a range of electromagnetic field exposures and brain tumor risk in the US Air Force. Cumulative extremely low frequency and radiofrequency/microwave electromagnetic field potential exposures were estimated from a job-exposure matrix developed for this study. Ionizing radiation exposures were obtained from personal dosimetry records. Men who were exposed to nonionizing electromagnetic fields had a small excess risk for developing brain tumors, with the extremely low frequency and radiofrequency/microwave age-race-senior military rank-adjusted odds ratios being 1.28 (95% confidence interval (Cl) 0.95-1.74) and 1.39 (95% Cl 1.01-1.90), respectively. By contrast, men who were exposed to ionizing radiation had an age-race-senior military rank-adjusted odds ratio of 0.58 (95% Cl 0.22-1.52). These results support a small association between extremely low frequency and radiofrequency/microwave electromagnetic field exposure and no association between ionizing radiation exposure and brain tumors in the US Air Force population. Military rank was consistently associated with brain tumor risk. Officers were more likely than enlisted men to develop brain tumors (age-race-adjusted odds ratio (OR) = 2.11, 95% Cl 1.48-3.01), and senior officers were at increased risk compared with all other US Air Force members (age-race-adjusted OR = 3.30, 95% Cl 1.99-5.45).

Grigor'ev IuG, Stepanov VS, [Forming of memory (imprinting) in chicks after prior low-level exposure to electromagnetic fields]. Radiats Biol Radioecol 38(2):223-231, 1998. [Article in Russian]

EMF of power density from 0.4 to 10 mW/cm2 can influence forming the memory (imprinting). Showed the possibility to fix EMF modulated in embryonic brain during the natal period and conservation of this information after birth.

Grigor'ev IuG, [Role of modulation in biological effects of electromagnetic radiation]. Radiats Biol Radioecol 36(5):659-670, 1996. [Article in Russian]

Data, describing a role of modulation of electromagnetic fields in development of biological effect, are considered. Outcomes of researches, indicating the dependence of a response of nervous and immune systems on a kind of modulation at low levels of effect, are represented. The necessity of the account of a role of modulation in an evaluation of electromagnetic danger is formulated.

Ha M, Lim HJ, Cho SH, Choi HD, Cho KY. Incidence of cancer in the vicinity of Korean AM radio transmitters. Arch Environ Health. 58(12):756-762, 2003.

Results of various studies have indicated a potential association between exposures to electrical and/or magnetic fields and risks of various cancers. The authors used a cross-sectional ecological study design to investigate such a potential association. In areas proximate to 42 amplitude modulated (AM) radio transmitters, 11 high-power study sites (i.e., areas exposed to 100-1500-kW transmission power) and 31 low-power study sites (i.e., areas exposed to 50-kW transmission power) were identified. The incidence of cancer within a 2-km radius of each transmitter was obtained from (a) Korean medical-insurance data for the years 1993 through 1996, (b) population census data for the year 1995, and (c) resident registration data for the year 1995. The authors calculated age-standardized rate ratios for total cancer, leukemia, malignant lymphoma, brain cancer, and breast cancer, and compared the incidence of cancer within 2 km of the high-power transmitters vs. the incidence within 2 km of the low-power transmitters. Four control areas for each high-power transmitter were also selected. The control areas were located in the same, or nearest adjacent, province as the high-power sites, but were at least 2 km from any of the transmitters. Indirect standardized observed/expected ratios for the high-power sites vs. control areas were calculated for each transmitter separately, and for 4 transmitter groupings defined by power level (i.e., 100 kW, 250 kW, 500 kW, and 1500 kW). The authors found no significant increase in age-standardized rate ratios of cancers for high-power vs. low-power sites, with the exceptions of total cancer and of brain cancer in women. Among the 11 high-power sites, there were significantly increased incidences of leukemia in 2 areas and of brain cancer in 1 area. Future studies should incorporate additional detailed exposure assessments and a strong analytical study design to explore the possible association between radiofrequency radiation from AM radio transmitters and cancer.

Habauzit D, Le Quément C, Zhadobov M, Martin C, Aubry M, Sauleau R, Le Dréan Y. Transcriptome Analysis Reveals the Contribution of Thermal and the Specific Effects in Cellular Response to Millimeter Wave Exposure. PLoS One. 2014 Oct 10;9(10):e109435. doi:10.1371/journal.pone.0109435. eCollection 2014.

Radiofrequency radiations constitute a new form of environmental pollution. Among them, millimeter waves (MMW) will be widely used in the near future for high speed communication systems. This study aimed therefore to evaluate the biocompatibility of MMW at 60 GHz. For this purpose, we used a whole gene expression approach to assess the effect of acute 60 GHz exposure on primary cultures of human keratinocytes. Controls were performed to dissociate the electromagnetic from the thermal effect of MMW. Microarray data were validated by RT-PCR, in order to ensure the reproducibility of the results. MMW exposure at 20 mW/cm2, corresponding to the maximum incident power density authorized for public use (local exposure averaged over 1 cm2), led to an increase of temperature and to a strong modification of keratinocyte gene expression (665 genes differentially expressed). Nevertheless, when temperature is artificially maintained constant, no modification in gene expression was observed after MMW exposure. However, a heat shock control did not mimic exactly the MMW effect, suggesting a slight but specific electromagnetic effect under hyperthermia conditions (34 genes differentially expressed). By RT-PCR, we analyzed the time course of the transcriptomic response and 7 genes have been validated as differentially expressed: ADAMTS6, NOG, IL7R, FADD, JUNB, SNAI2 and HIST1H1A. Our data evidenced a specific electromagnetic effect of MMW, which is associated to the cellular response to hyperthermia. This study raises the question of co-exposures associating radiofrequencies and other environmental sources of cellular stress.

Haider T, Knasmueller S, Kundi M, Haider M, Clastogenic effects of radiofrequency radiations on chromosomes of Tradescantia. Mutat Res 324(1-2):65-68, 1994.

The clastogenicity of electromagnetic fields (EMF) has so far been studied only under laboratory conditions. We used the Tradescantia-micronucleus (Trad-MCN) bioassay in an in situ experiment to find out whether short-wave electromagnetic fields used for broadcasting (10-21 MHz) may show genotoxic effects. Plant cuttings bearing young flower buds were exposed (30 h) on both sides of a slewable curtain antenna (300/500 kW, 40-170 V/m) and 15 m (90 V/m) and 30 m (70 V/m) distant from a vertical cage antenna (100 kW) as well as at the neighbors living near the broadcasting station (200 m, 1-3 V/m). The exposure at both sides of the slewable curtain antenna was performed simultaneously within cages, one of the Faraday type shielding the field and one non-shielding mesh cage. Laboratory controls were maintained for comparison. Higher MCN frequencies than in laboratory controls were found for all exposure sites in the immediate vicinity of the antennae, where the exposure standards of the electric field strength of the International Radiation Protection Association (IRPA) were exceeded. The results at all exposure sites except one were statistically significant. Since the parallel exposure in a non-shielding and a shielding cage also revealed significant differences in MCN frequencies (the latter showing no significant differences from laboratory controls), the clastogenic effects are clearly attributable to the short-wave radiation from the antennae.

Hallberg O, Johansson O. Melanoma incidence and frequency modulation (FM) broadcasting. Arch Environ Health. 57(1):32-40, 2002.

The incidence of melanoma has been increasing steadily in many countries since 1960, but the underlying mechanism causing this increase remains elusive. The incidence of melanoma has been linked to the distance to frequency modulation (FM) broadcasting towers. In the current study, the authors sought to determine if there was also a related link on a larger scale for entire countries. Exposure-time-specific incidence was extracted from exposure and incidence data from 4 different countries, and this was compared with reported age-specific incidence of melanoma. Geographic differences in melanoma incidence were compared with the magnitude of this environmental stress. The exposure-time-specific incidence from all 4 countries became almost identical, and they were approximately equal to the reported age-specific incidence of melanoma. A correlation between melanoma incidence and the number of locally receivable FM transmitters was found. The authors concluded that melanoma is associated with exposure to FM broadcasting.

Hao YT, Pei LP, Chen CH, Yang XS, Zhang GB, Deng ZH, Yu ZP. [Effects of occupational microwave irradiation on heat shock protein 70 expressions in rat hippocampus.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):553-556, 2009. [Article in Chinese]

OBJECTIVE: To study the change of heat shock protein (HSP)70 expression after exposure to occupational microwave in rats hippocampus, and explore the role of HSP70 in the mechanism of bio-effect of microwave irradiation. METHODS: The animal model was established by whole body exposures in 90, 5 W/cm(2) microwave irradiation field for 20 min in rats. Changes of the mRNA of hsp70 expressions in rat hippocampus at different time were studied by RT-PCR, and the protein change by Western blot. RESULTS: The mRNA and protein expression of hsp70 in rat hippocampus increased after 90 W/cm(2) and 5 W/cm(2) microwave irradiation for 20 min. The anal temperature and the value of SAR increased significantly. These changes were positively correlated with power and irradiation time of microwave. The results indicated that microwave irradiation led to HSP70 syntheses effectively. CONCLUSION: Microwave irradiation can obviously induce the thermal effect and activate HSP70, and initiate the endogens protective mechanism of central nervous system.

Hardell L, Nasman A, Ohlson CG, Fredrikson M. Case-control study on risk factors for testicular cancer. Int J Oncol 13(6):1299-1303, 1998.

Occupational exposures were assessed in a case-control study on testicular cancer using self administered questionnaires. Answers were obtained for 148 (91%) cases and 314 (87%) controls. Of the cases 101 had seminoma and 47 had embryonal testicular cancer. Occupational plastics work yielded odds ratio (OR) 2.9 with 95% confidence interval (CI) 1.3-6.5. Increased risk was found for embryonal cancer regarding farming (OR 3.1; CI 1.03-9.1) and contact with farm animals (OR 3.3; CI 1.00-10.9), but not for seminoma. For all testicular cancer exposure to insects repellents, mostly containing N,N-diethyl-m-toluamide (DEET) gave OR 1.7; CI 1.03-2.8, with a dose-response effect. Somewhat increased risks were found for amateur radio operators (OR 2.2; CI 0.7-6.6), work with radar equipment (OR 2.0; CI 0.3-14.2) and engineers in electronics and telecommunication industry (OR 2.3; CI 0.8-6.7) based on few exposed subjects, however. Video display unit work gave OR 1.5; CI 0.98-2.3 and for exposure 480 working days (median number) the risk increased further to OR 1.8; CI 1.1-3.2. Because of low numbers of exposed subjects in some calculations some of these results might be spurious and need to be further studied.

Havas M. **Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis.**Electromagn Biol Med. **25(4):259-268, 2006.**

Dirty electricity is a ubiquitous pollutant. It flows along wires and radiates from them and involves both extremely low frequency electromagnetic fields and radio frequency radiation. Until recently, dirty electricity has been largely ignored by the scientific community. Recent inventions of metering and filter equipment provide scientists with the tools to measure and reduce dirty electricity on electrical wires. Several case studies and anecdotal reports are presented. Graham/Stetzer (GS) filters have been installed in schools with sick building syndrome and both staff and students reported improved health and more energy. The number of students needing inhalers for asthma was reduced in one school and student behavior associated with ADD/ADHD improved in another school. Blood sugar levels for some diabetics respond to the amount of dirty electricity in their environment. Type 1 diabetics require less insulin and Type 2 diabetics have lower blood sugar levels in an electromagnetically clean environment. Individuals diagnosed with multiple sclerosis have better balance and fewer tremors. Those requiring a cane walked unassisted within a few days to weeks after GS filters were installed in their home. Several disorders, including asthma, ADD/ADHD, diabetes, multiple sclerosis, chronic fatigue, fibromyalgia, are increasing at an alarming rate, as is electromagnetic pollution in the form of dirty electricity, ground current, and radio frequency radiation from wireless devices. The connection between electromagnetic pollution and these disorders needs to be investigated and the percentage of people sensitive to this form of energy needs to be determined.

Havas M, Marrongelle J. Replication of heart rate variability provocation study with 2.4-GHz cordless phone confirms original findings. Electromagn Biol Med. 32(2):253-266, 2013.

This is a replication of a study that we previously conducted in Colorado with 25 subjects designed to test the effect of electromagnetic radiation generated by the base station of a cordless phone on heart rate variability (HRV). In this study, we analyzed the response of 69 subjects between the ages of 26 and 80 in both Canada and the USA. Subjects were exposed to radiation for 3-min intervals generated by a 2.4-GHz cordless phone base station (3-8 $\mu W/cm^2$). A few participants had a severe reaction to the radiation with an increase in heart rate and altered HRV indicative of an alarm response to stress. Based on the HRV analyses of the 69 subjects, 7% were classified as being "moderately to very" sensitive, 29% were "little to moderately" sensitive, 30% were "not to little" sensitive and 6% were "unknown". These results are not psychosomatic and are not due to electromagnetic interference. Twenty-five percent of the subjects' self-proclaimed sensitivity corresponded to that based on the HRV analysis, while 32% overestimated their sensitivity and 42% did not know whether or not they were electrically sensitive. Of the 39 participants who claimed to experience some electrical hypersensitivity, 36% claimed they also reacted to a cordless phone and experienced heart symptoms and, of these, 64% were classified as having some degree of electrohypersensitivity (EHS) based on their HRV response. Novel findings include documentation of a delayed response to radiation. Orthostatic HRV testing combined with provocation testing may provide a diagnostic tool for some sufferers of EHS when they are exposed to electromagnetic emitting devices. The protocol used underestimates reaction to electromagnetic radiation for those who have a delayed autonomic nervous system reaction and it may under diagnose those who have adrenal exhaustion as their ability to mount a response to a stressor is diminished.

Hess DJ, Coley JS. Wireless smart meters and public acceptance: The environment, limited choices, and precautionary politics. Public Underst Sci. 2012 Nov 6. [Epub ahead of print]

Wireless smart meters (WSMs) promise numerous environmental benefits, but they have been installed without full consideration of public acceptance issues. <u>Although societal-implications research and regulatory policy have focused on privacy, security, and accuracy issues, our research indicates that health concerns have played an important role in the public policy debates that have emerged in California</u>. Regulatory bodies do not recognize non-thermal health effects for non-ionizing electromagnetic radiation, but both homeowners and counter-experts have contested the official assurances that WSMs pose no health risks. Similarities and differences with the existing social science literature on mobile phone masts are discussed, as are the broader political implications of framing an alternative policy based on an opt-out choice. <u>The research suggests conditions under which health-oriented precautionary politics can be particularly effective, namely, if there is a mandatory technology, a network of counter-experts, and a broader context of democratic contestation.</u>

Hinrikus H, Parts M, Lass J, Tuulik V. Changes in human EEG caused by low level modulated microwave stimulation. Bioelectromagnetics. 25(6):431-440, 2004.

This study focuses on the effect of low level microwave radiation on human EEG alpha and theta rhythms. During the experiment, 20 healthy volunteers were exposed to a 450 MHz microwaves with 7 Hz on-off modulation. The field power density at the scalp was 0.16 mW/cm2. Signals from the following EEG channels were used: FP1, FP2, P3, P4, T3, T4, O1, and O2. The experimental protocol consisted of one cycle of short term photic and ten cycles of the repetitive microwave stimulation. The changes caused by photic as well as microwave stimulation were more regular on the alpha rhythm. <u>In the majority of cases, photic stimulation caused changes in the EEG energy level in the occipital and microwave stimulation in the frontal region. Our experimental results demonstrated that</u>

microwave stimulation effects became apparent, starting from the third stimulation cycle. Changes varied strongly from subject to subject. Therefore, photic and microwave exposure did not cause statistically significant changes in the EEG activity level for the whole group. For some subjects, clear tendencies of changes in microwave on-off cycles were noticeable.

Hjollund NH, Bonde JP, Skotte J, Semen analysis of personnel operating military radar equipment. Reprod Toxicol 11(6):897, 1997.

This is a preliminary survey of semen quality among Danish military personnel operating mobile ground-to-air missile units that use several microwave emitting radar systems. The maximal mean exposure was estimated to be 0.01 mW/cm2. The median sperm density of the military personnel was significantly low compared to the references. The difference is either due to chance, uncontrolled bias, or nonthermal effects of transitory microwaves.

Hocking B. Management of radiofrequency radiation overexposures. Aust Fam Physician 30(4):339-342, 2001.

BACKGROUND: Radiofrequency radiation (RFR) has been in use for some time but is now proliferative with the burgeoning radiocommunications industry. OBJECTIVE: To inform the profession of the possible health effects from overexposure to radiofrequency radiation (RFR) and the clinical approach to cases. An introduction to the health effects of overexposure to RFR is given. A clinical approach to integrating the patient's symptoms and the circumstances of the exposure is given. Emergency treatment and ongoing care is outlined, and sources of expert advice given. CONCLUSION: Overexposure to RFR is a complex injury. Advice is given in this article for emergency care and planning ongoing care.

Hocking B, Gordon I. Decreased survival for childhood leukemia in proximity to television towers. Arch Environ Health. 58(9):560-564, 2003.

Previously, an increased risk of childhood leukemia was identified among children who resided in an inner ring (radius -4 km) of 3 municipalities surrounding television towers, compared with children who resided in an outer ring (radius approximately 4-12 km) of 6 municipalities surrounding, but farther away from, the towers, which are situated in North Sydney, Australia. In the current study, the authors examined the survival experience of these children for all childhood leukemias, and for acute lymphatic leukemia (International Statistical Classification of Diseases and Related Health Problems, 9th revision [ICD-9] rubric 204.0) in particular. Of 123 cases of acute lymphatic leukemia, 29 cases (16 of whom died) were in the inner ring of municipalities nearest the towers, and 94 cases (34 of whom died) occurred in the outer, more-distant ring. There was a significant difference in survival rates between the 2 groups (log-rank test, $p = 0.03$; Wilcoxon, $p = 0.05$). The 5-yr survival in the inner ring of municipalities was 55%, and in the outer ring was 71% (i.e., subjects in the inner ring were 23% less likely to survive than those in the outer ring); at 10 yr, survival in the inner and outer rings was 33% and 62%, respectively. Following adjustment, the mortality rate ratio that the authors used to compare the inner ring with the outer ring was 2.1 (95% confidence interval = 1.1, 4.0). There was an association between residential proximity to the television towers and decreased surv

Holly EA, Aston DA, Ahn DK, Smith AH. Intraocular melanoma linked to occupations and chemical exposures. Epidemiology 7(1):55-61, 1996.

We conducted a case-control study in the western United States to determine the relation between occupations or chemical exposures and increased risk of uveal melanoma. Among men (221 patients, 447 controls), we found increased risks for occupational groups who had intense exposure to ultraviolet light [odds ratio (OR) = 3.0; 95% confidence interval (CI) = 1.2-7.8], welding exposure (OR = 2.2; 95% CI = 1.3-3.5), and asbestos exposure (OR = 2.4; 95% CI = 1.5-3.9 for most likely exposed). The highest odds ratio was for the small number of men (nine cases, three controls) who were chemists, chemical engineers, and chemical technicians (OR = 5.9; 95% CI = 1.6-22.7). Odds ratios also were elevated for exposures to antifreeze, formaldehyde, pesticides, and carbon tetrachloride, but these findings, based on recall of specific chemical exposures, are more subject to recall bias than the findings based on occupational groups. (Also reported a significant increase risk in uveal melanoma with microwave/radar exposure.)

Hu S, Peng R, Wang C, Wang S, Gao Y, Dong J, Zhou H, Su Z, Qiao S, Zhang S, Wang L, Wen X.Neuroprotective effects of dietary supplement Kang-fu-ling against high-power microwave through antioxidant action. Food Funct. 2014 Jul 24. [Epub ahead of print]

Kang-fu-ling (KFL) is a polybotanical dietary supplement with antioxidant properties. This study aimed to evaluate the potential protective effects of KFL on cognitive deficit induced by high-power microwave (HPM) and the underlying mechanism for this neuroprotection. The electron spin resonance technique was employed to evaluate the free radical scavenging activity of KFL in vitro and KFL exhibited scavenging hydroxyl radical activity. KFL at doses of 0.75, 1.5 and 3 g kg-1 and vehicle were administered orally once daily for 14 days to male Wistar rats after being exposed to 30 mW cm-2 HPM for 15 minutes. KFL reversed HPM-induced memory loss and the histopathological changes in hippocampus of rats. In addition, KFL displayed a protective effect against HPM-induced oxidative stress and activated the nuclear factor-E2-related factor 2 (Nrf2) and its target genes in the hippocampus of rats. The Nrf2-antioxidant response element (ARE) signaling pathway may be involved in the neuroprotective effects of KFL against HPM-induced oxidative stress. In summary, the dietary supplement KFL is a promising natural complex, which ameliorates oxidative stress, with neuroprotective effects against HPM.

Hwang Y, Ahn J, Mun J, Bae S, Jeong YU, Vinokurov NA, Kim P. In vivo analysis of THz wave irradiation induced acute inflammatory response in skin by laser-scanning confocal microscopy. Opt Express. 22(10):11465-11475, 2014.

The recent development of THz sources in a wide range of THz frequencies and power levels has led to greatly increased interest in potential biomedical applications such as cancer and burn wound diagnosis. However, despite its importance in realizing THz wave based applications, our knowledge of how THz wave irradiation can affect a live tissue at the cellular level is very limited. In this study, an acute inflammatory response caused by pulsed THz wave irradiation on the skin of a live mouse was analyzed at the cellular level using intravital laser-scanning confocal microscopy. Pulsed THz wave (2.7 THz, 4 μs pulsewidth, 61.4 μJ per pulse, 3Hz repetition), generated using compact FEL, was used to irradiate an anesthetized mouse's ear skin with an average power of 260 mW/cm² for 30 minutes using a high-precision focused THz wave irradiation setup. In contrast to in vitro analysis using cultured cells at similar power levels of CW THz wave irradiation, no temperature change at the surface of the ear skin was observed when skin was examined with an IR camera. To monitor any potential inflammatory response, resident neutrophils in the same area of ear skin were repeatedly visualized before and after THz wave irradiation using a custom-built laser-scanning confocal microscopy system optimized for in vivo visualization. While non-irradiated control skin area showed no changes in the number of resident neutrophils, a massive recruitment of newly infiltrated neutrophils was observed in the THz wave irradiated skin area after 6 hours, which suggests an induction of acute inflammatory response by the pulsed THz wave irradiation on the skin via a non-thermal process.

Indulski JA, Makowiec-Dabrowska T, Zmyslony M, Siedlecka J, [Electromagnetic poles and reproduction]. Med Pr 48(5):585-603, 1997.
[Article in Polish]

The authors review epidemiological data concerning the relationship between reproduction disorders and the exposure to electromagnetic fields (EMF) emitted by power lines, industrial power-charged devices, diagnostic and therapeutical appliances, video display terminals (VDTs) and electric household devices. The studies involved the analysis of the EMF effect on female and male reproduction, including the risk of spontaneous abortion, still birth and premature birth, low birth weight and congenital malformations as well as on the progeny gender proportion, among persons employed under the condition of EMF exposure. It was observed that the findings were frequently inconsistent, i.e. under the same conditions of EMF exposure some date indicated its negative effect on the reproduction process and some did not. No data confirming an acute effect of occupational exposure to EMF on the risk of spontaneous abortion, low birth weight, congenital malformations or other reproduction disorders were obtained, however, the negative effect of EMF cannot be explicitly excluded.

Irgens A, Kruger K, Ulstein M, The effect of male occupational exposure in infertile couples in Norway. J Occup Environ Med 41(12):1116-1120, 1999.

The objective of the study was to assess whether reduced semen quality in infertile couples is associated with occupational exposures known to be hazardous to fertility. Results of the first semen analysis were linked to occupational exposure data from a self-administered questionnaire. Reduced semen quality was found in men exposed to electromagnetic fields (odds ratio, 3.22; confidence interval, 1.46 to 7.09). A tendency toward reduced semen quality was seen in commuters (OR, 1.52; CI, 0.89 to 2.59), shift workers (OR, 1.46; CI, 0.89 to 2.40), and men exposed to heavy metals (OR, 1.47; CI, 0.76 to 2.87). In general, the impact of occupational exposure on semen quality in infertile couples in Norway seemed to be minor. However, occupational exposure mapping is still important in individual infertility investigations.

Joseph W, Frei P, Röösli M, Vermeeren G, Bolte J, Thuróczy G, Gajšek P, Trček T, Mohler E, Juhász P, Finta V, Martens L. Between-country comparison of whole-body SAR from personal exposure data in urban areas.Bioelectromagnetics. 33(8):682-694, 2012.

In five countries (Belgium, Switzerland, Slovenia, Hungary, and the Netherlands), personal radio frequency electromagnetic field measurements were performed in different microenvironments such as homes, public transports, or outdoors using the same exposure meters. From the mean personal field exposure levels (excluding mobile phone exposure), whole-body absorption values in a 1-year-old child and adult male model were calculated using a statistical multipath exposure method and compared for the five countries. All mean absorptions (maximal total absorption of 3.4 μW/kg for the child and 1.8 μW/kg for the adult) were well below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) basic restriction of 0.08 W/kg for the general public. Generally, incident field exposure levels were well correlated with whole-body absorptions (SAR(wb)), although the type of microenvironment, frequency of the signals, and dimensions of the considered phantom modify the relationship between these exposure measures. Exposure to the television and Digital Audio Broadcasting band caused relatively higher SAR(wb) values (up to 65%) for the 1-year-old child than signals at higher frequencies due to the body size-dependent absorption rates. Frequency Modulation (FM) caused relatively higher absorptions (up to 80%) in the adult male.

Joseph W, Goeminne F, Vermeeren G, Verloock L, Martens L. In situ exposure to non-directional beacons for air traffic control.Bioelectromagnetics. 33(3):274-277, 2012.

In situ electromagnetic field exposure of workers and the general public due to non-directional beacons (NDB) for air traffic control is assessed and characterized. For occupational exposure, the maximal measured electric field value is 881.6 V/m and the maximal magnetic field value is 9.1 A/m. The maximum electric fields exceed the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference levels at all seven NDB sites, and the magnetic fields at two of the seven NDB sites (occupational exposure). Recommendations and compliance distances for workers and the general public are provided.

Joseph W, Goeminne F, Vermeeren G, Verloock L, Martens L.Occupational and public field exposure from communication, navigation, and radar systems used for air traffic control.Health Phys. 103(6):750-762, 2012.

ABSTRACT: Electromagnetic exposure (occupational and general public) to 14 types of air traffic control (ATC) systems is assessed. Measurement methods are proposed for in situ exposure assessment of these ATC systems. In total, 50 sites are investigated at 1,073 locations in the frequency range of 255 kHz to 24 GHz. For all installations, typical and maximal exposure values for workers and the general public are provided. Two of the 14 types of systems, Non-Directional Beacons (NDB) (up to 881.6 V m) and Doppler Very High Frequency (VHF) Omni-directional Range (DVOR) (up to 92.3 V m), exhibited levels requiring recommended minimum distances such that the ICNIRP reference levels are not exceeded. Cumulative exposure of all present radiofrequency (RF) sources is investigated, and it is concluded that the ATC source dominates the total exposure in its neighborhood.

Kakita Y, Kashige N, Murata K, Kuroiwa A, Funatsu M, Watanabe K, Inactivation of Lactobacillus bacteriophage PL-1 by microwave irradiation. Microbiol Immunol39(8):571-576, 1995.

The effect of microwave irradiation on the survival of bacteriophage PL-1, which is specific for Lactobacillus casei, was studied using a commercial 2,450 MHz microwave oven. The phages were inactivated by microwave irradiation according to almost first-order reaction kinetics. The rate of phage inactivation was not affected by the difference in the continuous or intermittent irradiation, nor by the concentrations of phages used, but was affected by the volume of phage suspensions, which prevented the loss of generated heat. <u>Microwave irradiation of phage suspensions produced a number of ghost phages with empty heads, but fragmentation of the tail was hardly noticed. The breakage of phage genome DNA was primarily caused by the heat generated by microwave irradiation, whereas the phage DNA was not affected by the same temperature achieved by heat from outside. Thus we concluded that the phage-inactivating effect of microwave irradiation was mainly attributed to a thermal microwave effect, which was much stronger than a simple thermal exposure.</u>

Kaliada TV, Nikitina VN, Liashko GG, Masterova Ilu, Shaposhnikova ES. [Experimental research on the biological action of the pulse-modulated microwave radiation created by shipboard radar stations]. Med Tr Prom Ekol (11):15-17, 1995. [Article in Russian]

The article represents experimental data on influence of impulse modulated microwave irradiation with discontinuous effects varying in intensity and exposure. Becavior, peripheral blood, biochemical and morphologic parameters were assessed in the laboratory animals exposed. <u>The response appeared to correlate with individual and typologic features of the examinees.</u>

Kalns J, Ryan KL, Mason PA, Bruno JG, Gooden R, Kiel JL. Oxidative stress precedes circulatory failure induced by 35-GHz microwave heating. Shock 13(1):52-59, 2000.

Sustained whole-body exposure of anesthetized rats to 35-GHz radio frequency radiation produces localized hyperthermia and hypotension, leading to circulatory failure and death. The physiological mechanism underlying the induction of circulatory failure by 35-GHz microwave (MW) heating is currently unknown. We hypothesized that oxidative stress may play a role in the pathophysiology of MW-induced circulatory failure and examined this question by probing organs for 3-nitrotyrosine (3-NT), a marker of oxidative stress. Animals exposed to low durations of MW that increased colonic temperature but were insufficient to produce hypotension showed a 5- to 12-fold increase in 3-NT accumulation in lung, liver, and plasma proteins relative to the levels observed in control rats that were not exposed to MW. 3-NT accumulation in rats exposed to MW of sufficient duration to induce circulatory shock returned to low, baseline levels. Leukocytes obtained from peripheral blood showed significant accumulation of 3-NT only at exposure levels associated with circulatory shock. 3-NT was also found in the villus tips and vasculature of intestine and within the distal tubule of the kidney but not in the irradiated skin of rats with MW-induced circulatory failure. The relationship between accumulation in liver, lung, and plasma proteins and exposure duration suggests either that nitro adducts are formed in the first 20 min of exposure and are then cleared or that synthesis of nitro adducts decreases after the first 20 min of exposure. Taken together, these findings suggest that oxidative stress occurs in many organs during MW heating. Because nitration occurs after microwave exposures that are not associated with circulatory collapse, systemic oxidative stress, as evidenced by tissue accumulation of 3-NT, is not correlated with circulatory failure in this model of shock.

Kemerov, S, Marinkev, M, Getova, D, Effects of low-intensity electromagnetic fields on behavioral activity of rats. ***Folia Med (Plovdiv)*** **41(3):75-80, 1999.**

The present study aimed at comparative assessment of the changes in behavioral activity of rats after exposing them to low intensity electromagnetic fields (EMFs) in the meter, decimeter and centimeter ranges. The experiments were carried out on 24 Wistar rats divided into 4 groups (1 control and 3 experimental), treated with different EMFs. The rats were irradiated on the head area at power density of 10 mW/cm2. Using a conventional shuttle box, the conditioned and non-conditioned responses and spontaneous motor activity of the rats were studied. The results suggest that exposure to EMFs in the three ranges can slow down the formation of conditioned responses--this was clearly marked in the rats exposed to meter EMFs, whereas the effects of centimeter EMFs were delayed in time. The behavioral effects were mild at athermal dosages and the animals adapted easily to exposure conditions. This study shows that determination of the effects of different EMFs should be done for each of the ranges separately; determination of the exact dosage of the electromagnetic fields can help to avoid their negative biological effects.

Kesari KK, Behari J. Fifty-gigahertz Microwave exposure effect of radiations on rat brain. Appl Biochem Biotechnol. 158(1):126-139,2009.

The object of this study is to investigate the effects of 50-GHz microwave radiation on the brain of Wistar rats. Male rats of the Wistar strain were used in the study. Animals of 60-day age were divided into two groups-group 1, sham-exposed, and group 2, experimental (microwave-exposed). The rats were housed in a temperature-controlled room (25 degrees C) with constant humidity (40-50%) and received food and water ad libitum. During exposure, rats were placed in Plexiglas cages with drilled ventilation holes and kept in an anechoic chamber. The animals were exposed for 2 h a day for 45 days continuously at a power level of 0.86 muW/cm(2) with nominal specific absorption rate 8.0 x 10(-4) w/kg. After the exposure period, the rats were killed and homogenized, and protein kinase C (PKC), DNA double-strand break, and antioxidant enzyme activity [superoxides dismutase (SOD), catalase, and glutathione peroxidase (GPx)] were estimated in the whole brain. Result shows that the chronic exposure to these radiations causes DNA double-strand break (head and tail length, intensity and tail migration) and a significant decrease in GPx and SOD activity ($p = <0.05$) in brain cells, whereas catalase activity shows significant increase in the exposed group of brain samples as compared with control ($p = <0.001$). In addition to these, PKC decreased significantly in whole brain and hippocampus ($p < 0.05$). All data are expressed as mean +/- standard deviation. <u>We conclude that these radiations can have a significant effect on the whole brain.</u>

Kittel A, Siklos L, Thuroczy G, Somosy Z, Qualitative enzyme histochemistry and microanalysis reveals changes in ultrastructural distribution of calcium and calcium-activated ATPases after microwave irradiation of the medial habenula. Acta Neuropathol (Berl) 92(4):362-368, 1996.

The localization of calcium and calcium-activated ATPases was investigated electron microscopically in the medial habenula of mice after whole body irradiation with modulated microwaves. In non-irradiated animals calcium-containing precipitates were seen in different subcellular compartments and were often localized on the luminal side of membranes of synaptic vesicles in nerve terminals. At 1 h after 16-Hz modulated microwave irradiation, the number of synaptic vesicles containing calcium precipitates decreased, and reaction products appeared at new locations: in the synaptic clefts and on non-synaptic surfaces of the neuronal plasma membrane. This modified calcium distribution remained unchanged for 24 h following irradiation. Calcium-activated "ecto"-localized ATPase was detected as a punctuated-linear distribution of the reaction product outlining whole areas of glial and neuronal plasma membrane in the habenula of control animals. This pattern did not change on microwave irradiation. However, a quercetin-sensitive "endo"-localized Ca(2+)-ATPase activity appeared in some nerve terminals 24 h after irradiation. <u>Thus, microwave irradiation can influence neuronal calcium homeostasis by inducing Ca2+ redistribution across the plasma membrane and by modifying Ca(2+)-ATPase activity.</u> However, no direct correlation between these effects could be demonstrated by the present study.

Kolodynski AA, Kolodynska VV, Motor and psychological functions of school

children living in the area of the Skrunda Radio Location Station in Latvia. Sci Total Environ 180(1):87-93, 1996.

This paper presents the results of experiments on school children living in the area of the Skrunda Radio Location Station (RLS) in Latvia. Motor function, memory and attention significantly differed between the exposed and control groups. Children living in front of the RLS had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased.

Kolomytseva MP, Gapeev AB, Sadovnikov VB, Chemeris NK. [Suppression of nonspecific resistance of the body under the effect of extremely high frequency electromagnetic radiation of low intensity] Biofizika. 47(1):71-77, 2002. [Article in Russian] **(I-M)**

The dynamics of leukocyte number and functional activity of peripheral blood neutrophils under whole-body exposure of healthy mice to low-intensity extremely-high-frequency electromagnetic radiation (EHF EMR, 42.0 GHz, 0.15 mW/cm2, 20 min daily) was studied. It was shown that the phagocytic activity of peripheral blood neutrophils was suppressed by about 50% ($p < 0.01$ as compared with the sham-exposed control) in 2-3 h after the single exposure to EHF EMR. The effect persisted for 1 day after the exposure, and then the phagocytic activity of neutrophils returned to the norm within 3 days. A significant modification of the leukocyte blood profile in mice exposed to EHF EMR for 5 days was observed after the cessation of exposures: the number of leukocytes increased by 44% ($p < 0.05$ as compared with sham-exposed animals), mostly due to an increase in the lymphocyte content. The supposition was made that EHF EMR effects can be mediated via the metabolic systems of arachidonic acid and the stimulation of adenylate cyclase activity, with subsequent increase in the intracellular cAMP level. The results indicated that the whole-body exposure of healthy mice to low-intensity EHF EMR has a profound effect on the indices of nonspecific immunity.

Kol'tsov IuV, Korolev VN, Kusakin SA, [Two-step exposure of biological objects to infrared laser and microwave radiation]. Biofizika 44(2):378-381, 1999. [Article in Russian]

The effect of two-step exposure of bacterial objects to infrared laser and microwave pulse radiations was studied. The effect is determined by the time interval between two excitation steps and pulse duration. It was shown that the biologically active dose of microwave radiation is much lower than that of infrared laser radiation; however, laser radiation induces a stronger cellular response. It was found that microwaves enhance the efficiency of infrared laser radiation.

Koveshnikov IV, Antipenko EN, [Quantitative patterns in the cytogenetic action of microwaves]. Radiobiologiia 31(1):149-151, 1991. [Article in Russian]

It was shown on hepatocytes of albino mongrel rats that the energy flow density (EFD) of 100 muW/cm2 approximated the level at which the mutagenic effects of microwaves started developing (3,000 MHz, pulse frequency 400 Hz, 60 days, 12 h a day). The severity of the mutagenic effects of radiation with EFD of 100, 500 and 2,500 muW/cm2 depended on the type of the microwave generation that was responsible for the energy loading variations. The increase in the total radiation energy levelled the mutagenic effects of microwaves of all three intensities.

Kulkybaev GA, Pospelov NI, [Changes in gastric electric activity and serum catecholamine level under the influence of electromagnetic microwaves]. Med Tr Prom Ekol (5):8-11, 2000. (Article in Russian)

Chronic experiments on 17 dogs revealed that ultrahigh-frequency electromagnetic waves applied on epigastric area and head induce a double-phase response: depressed electric activity of gaster and increased total catecholamines level during exposure, but higher gastric activity and lower levels of epinephrine and norepinephrine in 24 hours after each of 10 procedures and during 7 days after 10 procedures. Double-phase changes in electric activity of gaster could be explained by double-phase fluctuations of humoral division in chromaffin system.

Kumar S, Kesari KK, Behari J. Influence of microwave exposure on fertility of male rats. Fertil Steril.95(4):1500-1502, 2011.

The present study investigates the effect of 10-GHz microwave radiation on the fertility pattern of 70-day-old male rats (sham exposed and exposed), which were exposed for 2 h/d for 45 days continuously at a specific absorption rate of 0.014 W/kg and a power density of 0.21 mW/cm(2). Results show a significant change in the level of reactive oxygen species, histone kinase, apoptotic cells, and percentage of G(2)/M transition phase of cell cycle in the exposed group compared with the sham-exposed group. The study concludes that there is a significant effect of microwave radiations on the reproductive pattern in male rats, which is a causative factor of male infertility.

Kumar S, Kesari KK, Behari J. Evaluation of genotoxic effects in male Wistar rats following microwave exposure. Indian J Exp Biol. 48(6):586-592, 2010.

Wistar rats (70 days old) were exposed for 2 h a day for 45 days continuously at 10 GHz [power density 0.214 mW/cm2, specific absorption rate (SAR) 0.014 W/kg] and 50 GHz (power density 0.86 microW/cm2, SAR 8.0 x10(-4) W/kg). Micronuclei (MN), reactive oxygen species (ROS), and antioxidant enzymes activity were estimated in the blood cells and serum. These radiations induce micronuclei formation and significant increase in ROS production. Significant changes in the level of serum glutathione peroxidase, superoxide dismutase and catalase were observed in exposed group as compared with control group. It is concluded that microwave exposure can be affective at genetic level. This may be an indication of tumor promotion, which comes through the overproduction of reactive oxygen species.

Kumar S, Behari J, Sisodia R. Impact of microwave at X-band in the aetiology of male infertility. Electromagn Biol Med. 31(3):223-232, 2012.

Reports of declining male fertility have renewed interest in assessing the role of environmental and occupational exposures to electromagnetic fields (EMFs) in the aetiology of human infertility. Testicular functions are particularly susceptible to electromagnetic fields. The aim of the present work was to investigate the effect of 10-GHz EMF on male albino rat's reproductive system and to investigate the possible causative factor for such effect of exposure. The study was carried out in two groups of 70-day old adult male albino rats: a sham-exposed and a 10-GHz-exposed group (2 h a day for 45 days). Immediately after completion of the exposure, animals were sacrificed and sperms were extracted from the cauda and caput part of testis for the analysis of MDA, melatonin, and creatine kinase. Creatine kinase results revealed an increased level of phosphorylation that converts creatine to creatine phosphate in sperms after EMF exposure. EMF exposure also reduced the level of melatonin and MDA. <u>It is concluded that microwaveexposure could adversely affect male fertility by reducing availability of the above parameters. These results are indications of deleterious effects of these radiations on reproductive pattern of male rats.</u>

Kumar S, Behari J, Sisodia R. Influence of electromagnetic Fields on reproductive system of male rats.Int J Radiat Biol. 2012 Oct 19. [Epub ahead of print]

Purpose: Reports of declining male fertility have renewed interest in the role of environmental and occupational exposures in the etiology of human infertility. The aim of the present work is to investigate the effect of 10 GHz exposure on male Wistar rat's reproductive system and to find out the possible causative factors. Materials and methods: The study was divided into sham exposed and exposed groups. Seventy days old rats were exposed to 10 GHz microwave radiation for two hours per day for 45 days at power density 0.21mW/cm(2) and specific absorption rate (SAR) of 0.014W/kg. After the end of the experiment, blood samples were collected for the estimation of in vivo chromosomal aberration damage and micronucleus test. Spermatozoa were taken out for estimation of caspase3, comet assay, testosterone and electron microscopy and compared with sham exposed. Results: The study of scanning electron microscopic revealed shrinkage of the lumen of the seminiferous tubules. Apoptotic bodies were found in exposed group. A flow cytometry examination showed formation of micronuclei body in lymphocytes of exposed group. Comet assay confirmed DNA (deoxyribonucleic acid) strand break. Testosterone level was found significantly decreased with the shrinkage of testicular size. <u>Conclusions: 10 GHz field has an injurious effect on fertility potential of male exposed animals.</u>

Kumar V, Vats RP, Pathak PP. Harmful effects of 41 and 202 MHz radiations on some body parts and tissues. Indian J Biochem Biophys. 45(4):269-274, 2008.

Many types of invisible electromagnetic waves are produced in our atmosphere. When these radiations penetrate our body, electric fields are induced inside the body, resulting in the absorption of power, which is different for different body parts and also depends on the frequency of radiations. Higher power absorption may result into health problems. In this communication, effects of electromagnetic waves (EMW) of 41 and 202 MHz frequencies transmitted by the TV tower have been studied on skin, muscles, bone and fat of human. Using international standards for safe exposure limits of specific absorption rate (SAR), we have found the safe distance from TV transmission towers for two frequencies. It is suggested that transmission towers should be located away from the thickly populated areas and people should keep away from the transmission towers, as they radiate electromagnetic radiations that are harmful to some parts/tissues of body.

Kunjilwar KK, Behari J Effect of amplitude-modulated radio frequency radiation on cholinergic system of developing rats. Brain Res 601(1-2):321-324, 1993.

We examined the effect of long-term exposure to radio frequency radiation 147 MHz and its sub-harmonics 73.5 and 36.75 MHz amplitude modulated at 16 and 76 Hz (30-35 days, 3 h per day) on cholinergic systems in developing rat brain. A significant decrease in acetylcholine esterase activity was found in exposed rats as compared to the control. Decrease in acetylcholine esterase (AChE) activity was independent of carrier wave frequencies. A short-term exposure did not have any significant effect on AChE activity.

Lagorio S, Rossi S, Vecchia P, De Santis M, Bastianini L, Fusilli M, Ferrucci A, Desideri E, Comba P, Mortality of plastic-ware workers exposed to radiofrequencies. Bioelectromagnetics 18(6):418-421, 1997.

The mortality experience of a cohort of Italian plastic-ware workers exposed to radiofrequency (RF)-electromagnetic fields generated by dielectric heat sealers was investigated. Follow-up extended from 1962 to 1992. The standardised mortality ratio (SMR) analysis was restricted to 481 women workers, representing 78% of the total person-years at risk. Mortality from malignant neoplasms was slightly elevated, and increased risks of leukemia and accidents were detected. The all-cancer SMR was higher among women employed in the sealing department, where exposure to RF occurred, than in the whole cohort. This study raises interest in a possible association between exposure to RF radiation and cancer risk. However, the study power was very small, and the possible confounding effects of exposure to solvents and vinyl chloride monomer (VCM) could not be ruled out. The hypothesis of an increased risk of cancer after radiofrequency exposure should be further explored by means of analytical studies characterised by adequate power and more accurate exposure assessment.

Lalic H, Lekic A, Radosevic-Stasic B. Comparison of chromosome aberrations in peripheral blood lymphocytes from people occupationally exposed to ionizing and radiofrequency radiation. Acta Med Okayama 55(2):117-127, 2001.

The genotoxic effects of occupational exposure to ionizing and non-ionizing radiation were investigated in 25 physicians and nurses working in hospitals and in

20 individuals working at radio-relay stations. Examination was conducted by chromosome aberration analysis of peripheral blood lymphocytes. The data showed that total number of chromosome aberrations in people exposed to ionizing and radio-frequency radiation (4.08 +/- 0.37 and 4.35 +/- 0.5 on 200 scored metaphases, respectively) were almost equally higher than those of non-irradiated subjects. The increase was in proportion to the number of individuals having more that 5-aberration/200 metaphases. Acentric fragments comprised the most frequently seen type of aberration. The average numbers in examined groups (11.8 x 10(-3) and 14.8 x 10(-3) per cell, respectively), were significantly higher than 4.2 x 10(-3), which was observed in controls, unexposed individuals. Dicentric fragments were also frequent (4.8 x 10(-3) and 6.25 x 10(-3), respectively, vs. 0.52 x 10(-3) in control). In contrast, the frequency of chromatid breaks increased only after ionizing radiation (3.8 x 10(-3) vs. 0.26 x 10(-3) in control). A positive correlation between the total number of chromosome aberrations and cumulative 6-years dosage was also found. The data emphasized the dangerous effects of prolonged exposure to both types of radiation and indicated that chromosomal aberration analysis should be obligatory for individuals working at radio-relay stations.

Lee JW, Kim MS, Kim YJ, Choi YJ, Lee Y, Chung HW. Genotoxic effects of 3 T magnetic resonance imaging in cultured human lymphocytes.Bioelectromagnetics. 32(7):535-542, 2011.

The clinical and preclinical use of high-field intensity (HF, 3 T and above) magnetic resonance imaging (MRI) scanners have significantly increased in the past few years. However, potential health risks are implied in the MRI and especially HF MRI environment due to high-static magnetic fields, fast gradient magnetic fields, and strong radiofrequency electromagnetic fields. In this study, the genotoxic potential of 3 T clinical MRI scans in cultured human lymphocytes in vitro was investigated by analyzing chromosome aberrations (CA), micronuclei (MN), and single-cell gel electrophoresis. Human lymphocytes were exposed to electromagnetic fields generated during MRI scanning (clinical routine brain examination protocols: three-channel head coil) for 22, 45, 67, and 89 min. We observed a significant increase in the frequency of single-strand DNA breaks following exposure to a 3 T MRI. In addition, the frequency of both CAs and MN in exposed cells increased in a time-dependent manner. The frequencies of MN in lymphocytes exposed to complex electromagnetic fields for 0, 22, 45, 67, and 89 min were 9.67, 11.67, 14.67, 18.00, and 20.33 per 1000 cells, respectively. Similarly, the frequencies of CAs in lymphocytes exposed for 0, 45, 67, and 89 min were 1.33, 2.33, 3.67, and 4.67 per 200 cells, respectively. These results suggest that exposure to 3 T MRI induces genotoxic effects in human lymphocytes.

Lee W, Yang KL. Using medaka embryos as a model system to study biological effects of the electromagnetic fields on development and behavior. Ecotoxicol Environ Saf. 2014 Jul 29;108C:187-194. doi: 10.1016/j.ecoenv.2014.06.035. [Epub ahead of print].

The electromagnetic fields (EMFs) of anthropogenic origin are ubiquitous in our environments. The health hazard of extremely low frequency and radiofrequency EMFs has been investigated for decades, but evidence remains inconclusive, and animal studies are urgently needed to resolve the controversies regarding developmental toxicity of EMFs. Furthermore, as undersea cables and technological devices are increasingly used, the lack of information regarding the health risk of EMFs to aquatic organisms needs to be addressed. Medaka embryos (Oryzias latipes) have been a useful tool to study developmental toxicity in vivo due to their optical transparency. Here we explored the feasibility of using medaka embryos as a model system to study biological effects of EMFs on development. We also used a white preference test to investigate behavioral consequences of the EMF developmental toxicity. Newly fertilized embryos were randomly assigned to four groups that were exposed to an EMF with 3.2 kHz at the intensity of 0.12, 15, 25, or 60μT. The group exposed to the background 0.12μT served as the control. The embryos were exposed continually until hatch. They were observed daily, and the images were recorded for analysis of several developmental endpoints. Four days after hatching, the hatchlings were tested with the white preference test for their anxiety-like behavior. The results showed that embryos exposed to all three levels of the EMF developed significantly faster. The endpoints affected included the number of somites, eye width and length, eye pigmentation density, midbrain width, head growth, and the day to hatch. In addition, the group exposed to the EMF at 60μT exhibited significantly higher levels of anxiety-like behavior than the other groups did. <u>In conclusion, the EMF tested in this study accelerated embryonic development and heightened anxiety-like behavior. Our results also demonstrate that the medaka embryo is a sensitive and cost-efficient in vivo model system to study developmental toxicity of EMFs.</u>

Leshin VV, [Changes of neurocytes in CNS under general exposure to UHF field with local protection applied]. Med Tr Prom Ekol (5):5-8, 2000. [Article in Russian]

Experiments on white rats were performed to study influence of UHF field on cortical sensomotor area under general exposure or with the head shielded<u>. The changes in CNS caused by UHF field were not prevented completely by means of the shield. That is probably due to pathologic reflex impulses from the body receptors.</u>

Li BF, Guo GZ, Ren DQ, Zhang RB. Electromagnetic pulses induce fluctuations in blood pressure in rats. Int J Radiat Biol. 83(6):421-429, 2007.

Purpose: To investigate the effects of exposure to electromagnetic pulses (EMP) on functional indices of the cardiovascular system in male Sprague-Dawley rats. Materials and methods: A tapered parallel plate Gigahertz Transverse Electromagnetic cell (GTEM cell) with a flared rectangular coaxial transmission line was used to expose the rats to EMP (0.5 pps, total 200 pulses and whole-body averaged specific absorption rate 50 mW/kg at 200 kV/m or 75 mW/kg at

400 kV/m). Concurrent sham-exposed animals were used as controls. Cardiovascular functions, namely, heart rate, and systolic, mean and diastolic blood pressures were measured immediately and up to 4 weeks post-exposure using a non-invasive tail-cuff photoelectric sensor sphygmomanometer. Results: The heart rates in sham- and EMP-exposed rats were not significantly changed. In the exposed rats, increased systolic blood pressure (SBP) occurred at 0 h and decreased SBP occurred at 1 day and 3 days after exposure. Significantly higher diastolic blood pressure (DBP) was found at 0 h and significantly lower DBP was found at 12 h, 1 day, and 1 month after exposure. Significantly higher mean arterial pressure (MAP) was noted at 0 h and significantly lower MAP was noted at 1 day. Conclusions: Significant alterations in arterial blood pressure were observed in rats exposed to EMP exposure while heart rate was not altered.

Li C, Zhan C, Long Y, Gu H, Deng Y, Jiang Y, Tang M, Tang C, Luo S, [Some biochemical indexes in white rabbit's blood affected by acute high intensity microwave]. ***Hua Hsi I Ko Ta Hsueh Hsueh Pao*** **;26(2):206-209, 1995.** [Article in Chinese]

Irradiation of white rabbits by 10, 50, 100 and 200 mW/cm2 microwave respectively can cause the disorder of protein metabolism, the abnormality of blood sugar, and the change of the activity of serum alpha-hydroxybutyrate dehydrogenase, lactate dehydrogenase, glutamic oxalacetic transaminase, glutamic pyruvic transaminase, acid phosphatase ect. These changes can be used as indexes in the evaluation of the effect of acute high intensity microwave exposure. The effect on the organism mainly depends on the intensity of exposure provided the dose of microwave remains the same.

Li X, Hu XJ, Peng RY, Gao YB, Wang SM, Wang LF, Xu XP, Su ZT, Yang GS. [A aquaporin 4 expression and effects in rat hippocampus after microwave radiation.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):534-538, 2009. [Article in Chinese]

OBJECTIVE: To investigate the expression of aquaporin 4 (AQP4) after microwave exposure and the correlation with the brain injury by radiation. METHODS: 70 male rats were exposed to microwave whose average power density was 0, 10, 30 and 100 mW/cm(2) respectively. Rats were sacrificed at 6 h, 1 d, 3 d and 7 d after exposure. Immunohistochemistry and Western blot were used to detect the expression of AQP4 in protein level in rat hippocampus, and the expression of AQP4 in gene level was measured by in situ hybridization and RT-PCR. RESULTS: The expression of AQP4 in rat hippocampus was abnormal after 10, 30, 100 mW/cm(2) microwave exposure. The protein level showed increased at first and then recovered at 10 and 30 mW/cm(2) groups, while increased progressively in 100 mW/cm(2) group within 14 d (P < 0.01). The gene expression of AQP4 was increased (0.51 +/- 0.02) at the beginning (6 h) and then regained after 10 mW/cm(2) microwave exposure, while in 30 and 100 mW/cm(2) groups, it rose to the peak at 7 d (0.46 +/- 0.02 and 0.43 +/- 0.08) and didn't get back (P = 0.004; P = 0.012). CONCLUSION: Microwave radiation can increase the expression of AQP4 in rat hippocampus. The change might participate in the process of increasing permeability of blood-brain barrier and lead to the brain edema after microwave radiation.

Lim JI, Fine SL, Kues HA, Johnson MA. Visual abnormalities associated with high-energy microwave exposure. Retina 13(3):230-233, 1993.

A 44-year-old man was accidentally exposed to high-energy microwave irradiation. After resolution of facial erythema and iritis, he noted a foreign body sensation and blurring of vision. Ophthalmoscopic examination showed bilateral, small hard drusen. Ancillary tests were consistent with abnormal cone function. Electroretinogram testing revealed a marked decrease in the flicker electroretinogram. Results of D15 and Farnsworth Munsel Hue 100 color tests were abnormal. Two years later, the patient's visual acuity was stable at 20/25 in both eyes; however, results of flicker electroretinogram test remain markedly decreased. (comment by: Appleton B, Osepchuk J, Cohen J. A case of color vision abnormality and reduced amplitude of the 30 Hz flicker dark-adapted electroretinographic (ERG) Retina 15(2):170-172, 1995.)

Litovitz TA, Krause D, Penafiel M, Elson EC, Mullins JM, The role of coherence time in the effect of microwaves on ornithine decarboxylase activity. Bioelectromagnetics 14(5):395-403, 1993.

Previously, we demonstrated the requirements for a minimum coherence time of an applied, small amplitude (10 microT) ELF magnetic field if the field were to produce an enhancement of ornithine decarboxylase activity in L929 fibroblasts. Further investigation has revealed a remarkably similar coherence time phenomenon for enhancement of ornithine decarboxylase activity by amplitude-modulated 915 MHz microwaves of large amplitude (SAR 2.5 W/kg). Microwave fields modulated at 55, 60, or 65 Hz approximately doubled ornithine decarboxylase activity after 8 h. Switching modulation frequencies from 55 to 65 Hz at coherence times of 1.0 s or less abolished enhancement, while times of 10 s or longer provided full enhancement. Our results show that the microwave coherence effects are remarkably similar to those observed with ELF fields.

Litovitz, TA, Penafiel, LM, Farrel, JM, Krause, D, Meister, R, Mullins, JM Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise. Bioelectromagnetics 18(6):422-430, 1997.

We have previously demonstrated that microwave fields, amplitude modulated (AM) by an extremely low-frequency (ELF) sine wave, can induce a nearly twofold enhancement in the activity of ornithine decarboxylase (ODC) in L929 cells at SAR levels of the order of 2.5 W/kg. Similar, although less pronounced, effects were also observed from exposure to a typical digital cellular phone test signal of the same power level, burst modulated at 50 Hz. We have also shown that ODC enhancement in L929 cells produced by exposure to ELF fields can be inhibited by superposition of ELF noise. In the present study, we explore the possibility that similar inhibition techniques can be used to suppress the microwave response. We concurrently exposed L929 cells to 60 Hz AM microwave fields or a 50 Hz burst-modulated DAMPS (Digital Advanced Mobile Phone System) digital cellular phone field at levels known to produce ODC enhancement, together with band-limited 30-100 Hz ELF noise with root mean square amplitude of up to 10 microT. All exposures were carried out for 8 h, which was previously found to yield the peak microwave response. In both cases, the ODC enhancement was found to decrease exponentially as a function of the noise root mean square amplitude. With 60 Hz AM microwaves, complete inhibition was obtained with noise levels at or above 2 microT. With the DAMPS digital cellular phone signal, complete inhibition occurred with noise levels at or above 5 microT. These results suggest a possible practical means to inhibit biological effects from exposure to both ELF and microwave fields.

Liu YQ, Gao YB, Dong J, Yao BW, Zhao L, Peng RY. Pathological changes in the sinoatrial node tissues of rats caused by pulsed microwave exposure. Biomed Environ Sci. 28(1):72-75, 2015.

To observe microwave induced dynamic pathological changes in the sinus nodes, wistar rats were exposed to 0, 5, 10, 50 mW/cm2 microwave. In 10 and 50 mW/cm2 groups, disorganized sinoatrial node cells, cell swelling, cytoplasmic condensation, nuclear pyknosis, and anachromasis, swollen, and empty mitochondria, and blurred and focally dissolved myofibrils could be detected from 1 to 28 d, while reduced parenchymal cells, increased collagen fibers, and extracellular matrix remodeling of interstitial cells were observed from 6 to 12 months. In conclusion, 10 and 50 mW/cm2 microwave could cause structural damages in the sinoatrial node and extracellular matrix remodeling in rats.

Lokhmatova SA, [The effect of low-intensity prolonged impulse electromagnetic irradiation in the UHF range on the testes and the appendages of the testis in rats]. Radiats Biol Radioecol 34(2):279-285, 1994. [Article in Russian]

The influence of the long (4 months, 2 hr/day) impulsive electromagnetic irradiation with the power density of 0.25 mW/cm2 on the testes and epididymides was studied. The results demonstrate the high sensitivity of the rat testes and epididymides to electromagnetic field of 3 GHz. Some destructive changes both in the seminiferous tubules and testicular tissue were found. The full recovery has not been observed even 4 months after irradiation was finished.

Lu ST, Mathur SP, Akyel Y, Lee JC, Ultrawide-band electromagnetic pulses induced hypotension in rats. Physiol Behav 65(4-5):753-761, 1999; Corrected and republished in Physiol Behav;67(3):753-761, 1999.

The ultrawide-band (UWB) electromagnetic pulses are used as a new modality in radar technology. Biological effects of extremely high peak E-field, fast rise time, ultrashort pulse width, and ultrawide band have not been investigated heretofore due to the lack of animal exposure facilities. A new biological effects database is needed to establish personnel protection guidelines for these new type of radiofrequency radiation. Functional indices of the cardiovascular system (heart rate, systolic, mean, and diastolic pressures) were selected to represent biological end points that may be susceptible to the UWB radiation. A noninvasive tail-cuff photoelectric sensor sphygmomanometer was used. Male Wistar-Kyoto rats were subjected to sham exposure, 0.5-kHz (93 kV/m, 180 ps rise time, 1.00 ns pulse width, whole-body averaged specific absorption rate, SAR = 70 mW/kg) or a 1-kHz (85 kV/m, 200 ps rise time, 1.03 ns pulse width, SAR = 121 mW/kg) UWB fields in a tapered parallel plate GTEM cell for 6 min. Cardiovascular functions were evaluated from 45 min to 4 weeks after exposures. Significant decrease in arterial blood pressures (hypotension) was found. In contrast, heart rate was not altered by these exposures. The UWB radiation-induced hypotension was a robust, consistent, and persistent effect.

Lushnikov KV, Gapeev AB, Sadovnikov VB, Cheremis NK. [Effect of extremely high frequency electromagnetic radiation of low intensity on parameters of humoral immunity in healthy mice.] Biofizika 46(4):753-760, 2001. [Article in Russian]

The modification of indices of the humoral immune response to thymus-dependent antigen (sheep erythrocytes) after a whole-body exposure of healthy mice to low-intensity extremely-high-frequency electromagnetic radiation was studied. Male NMRI mice were exposed in the far-field zone of horn antenna at a frequency of 42.0 GHz and energy flux density of 0.15 mW/cm2 under different regimes: once for 20 min, for 20 min daily during 5 and 20 successive days before immunization, and for 20 min daily during 5 successive days after immunization throughout the development of the humoral immune response. The intensity of the humoral immune response was estimated on day 5 after immunization by the number of antibody-forming cells of the spleen and antibody titers. Changes in cellularity of the spleen, thymus and red bone marrow were also assessed. The indices of humoral immunity and cellularity of lymphoid organs changed insignificantly after acute exposure and series of 5 exposures before and after immunization of the animals. However, after repeated exposures for 20 days before immunization, a statistically significant reduction of thymic cellularity by 17.5% ($p < 0.05$) and a decrease in cellularity of the spleen by 14.5% ($p < 0.05$) were revealed. The results show that low-intensity extremely-high-frequency electromagnetic radiation with the frequency and energy flux density used does not influence the humoral immune response intensity in healthy mice but influences immunogenesis under multiple repeated exposures.

Luukkonen J, Hakulinen P, Mäki-Paakkanen J, Juutilainen J, Naarala J. Enhancement of chemically induced reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells by 872MHz radiofrequency radiation. Mutat Res. 662(1-2):54-58, 2009.

The objective of the study was to investigate effects of 872MHz radiofrequency (RF) radiation on intracellular reactive oxygen species (ROS) production and DNA damage at a relatively high SAR value (5W/kg). The experiments also involved combined exposure to RF radiation and menadione, a chemical inducing intracellular ROS production and DNA damage. The production of ROS was measured using the fluorescent probe dichlorofluorescein and DNA damage was evaluated by the Comet assay. Human SH-SY5Y neuroblastoma cells were exposed to RF radiation for 1h with or without menadione. Control cultures were sham exposed. Both continuous waves (CW) and a pulsed signal similar to that used in global system for mobile communications (GSM) mobile phones were used. Exposure to the CW RF radiation increased DNA breakage ($p<0.01$) in comparison to the cells exposed only to menadione. Comparison of the same groups also showed that ROS level was higher in cells exposed to CW RF radiation at 30 and 60min after the end of exposure ($p<0.05$ and $p<0.01$, respectively). No effects of the GSM signal were seen on either ROS production or DNA damage. The results of the present study suggest that 872MHz CW RF radiation at 5W/kg might enhance chemically induced ROS production and thus cause secondary DNA damage. However, there is no known mechanism that would explain such effects from CW RF radiation but not from GSM modulated RF radiation at identical SAR.

Maillefer RH, Quock RM. Naltrexone-sensitive analgesia following exposure of mice to 2450-MHz radiofrequency radiation. Physiol Behav 52(3):511-514, 1992.

To determine whether exposure to radiofrequency radiation (RFR) would induce sufficient thermal stress to activate endogenous opioid mechanisms, male Swiss Webster mice were exposed to 10, 15, and 20 mW/cm2 RFR in a 2450-MHz waveguide system for 10 min at specific absorption rates (SARs) of 23.7, 34.6, and 45.5 W/kg, respectively, then tested in the abdominal constriction paradigm. Confinement in the RFR exposure chamber alone did not appreciably alter body temperature but did appear to induce a stress-associated analgesia that was not blocked by naltrexone. Exposure of confined mice to RFR raised body temperature and further increased analgesia in an SAR-dependent manner. The high SAR-induced analgesia, but not the hyperthermia, was blocked by naltrexone. These findings suggest that 1) RFR produces SAR-dependent hyperthermia and analgesia, and 2) RFR-induced analgesia is mediated by opioid mechanisms while confinement-induced analgesia involves nonopioid mechanisms.

Manta AK, Stravopodis DJ, Papassideri IS, Margaritis LH. Reactive oxygen species elevation and recovery in Drosophila bodies and ovaries following short-term and long-term exposure to DECT base EMF. Electromagn Biol Med. 2013 Jun 19. [Epub ahead of print]

Abstract The objective of this study was to approach the basic mechanism(s) underlying reported ovarian apoptotic cell death and fecundity decrease induced by nonionizing radiation (NIR) in Drosophila melanogaster. ROS (Reactive Oxygen Species) levels were measured in the bodies and the ovaries of (sexually mature) 4-day-old flies, following exposure for 0.5, 1, 6, 24 and 96 h to a wireless DECT (Digital Enhanced Cordless Telephone) base radiation (1.88-1.90 GHz). Electrical field intensity was 2.7 V/m, measured within the fly vials and calculated SAR (Specific Absorption Rate) value = 0.009 W/Kg. Male and female bodies showed twofold increase in ROS levels ($p < 0.001$) after 6 h of exposure, slightly increasing with more irradiation (24 and 96 h). Ovaries of exposed females had a quick response in ROS increase after 0.5 h (1.5-fold, $p < 0.001$), reaching 2.5-fold after 1 h with no elevation thereafter at 6, 24 and 96 h. ROS levels returned to normal, in the male and the female bodies 24 h after 6 h of exposure of the flies ($p < 0.05$) and in the ovaries 4 h after 1 h exposure of the females ($p < 0.05$). It is postulated that the pulsed (at 100 Hz rate and 0.08 ms duration) idle state of the DECT base radiation is capable of inducing free radical formation albeit the very low SAR, leading rapidly to accumulation of ROS in a level-saturation manner under continuous exposure, or in a recovery manner after interruption of radiation, possibly due to activation of the antioxidant machinery of the organism.

Mason PA, Escarciga R, Doyle JM, Romano WF, Berger RE, Donnellan JP, Amino acid concentrations in hypothalamic and caudate nuclei during microwave-induced thermal stress: analysis by microdialysis. Bioelectromagnetics 18(3):277-283, 1997.

Exposure to radiofrequency radiation (RFR) may produce thermal responses. Extracellular amino acid concentrations in the hypothalamus (Hyp) and caudate nucleus (CN) were measured by using in vivo microdialysis before and during exposure to RFR. Under urethane anesthetic, each rat was implanted stereotaxically with a nonmetallic microdialysis probe and temperature probe guides and then placed in the exposure chamber. The rat laid on its right side with its head and neck placed directly under the wave guide. Temperature probes were placed in the left brain, right brain, face (subcutaneously), left tympanum, and rectum. Each microdialysis sample was collected over a 20 min period. The microdialysis probe was perfused for 2 h before the rat was exposed to 5.02 GHz radiation (10 microseconds pulse width, 1000 pulses/s). The right and left sides of the brain were maintained at approximately 41.2 and 41.7 degrees C, respectively, throughout a 40 min exposure period. Initially when the brain was being heated to these temperatures, the time-averaged specific absorption rates (SARs) for the right and left sides of the brain were 29 and 40 W/kg, respectively. Concentrations of aspartic acid, glutamic acid, serine, glutamine, and glycine in dialysate were determined by using high-pressure liquid chromatography with electrochemical detection. In the Hyp and CN, the concentrations of aspartic acid, serine, and glycine increased significantly during RFR exposure ($P < .05$). These results indicate that RFR-induced thermal stress produces a general change in the amino acid concentrations that is not restricted to thermoregulatory centers. Changes in the concentrations of glutamic acid (Hyp, $P = .16$; CN, $P = .34$) and glutamine (Hyp, $P = .13$; CN, $P = .10$) were not statistically significant. Altered amino acid concentrations may reveal which brain regions are susceptible to damage in response to RFR-induced thermal stress.

Masuda H, Hirata A, Kawai H, Wake K, Watanabe S, Arima T, Poulletier de Gannes F, Lagroye I, Veyret B. Local exposure of the rat cortex to radiofrequency electromagnetic fields increases local cerebral blood flow along with temperature. J Appl Physiol. 110(1):142-148, 2011.

Few studies have shown that local exposure to radiofrequency electromagnetic fields (RF) induces intensity-dependent physiological changes, especially in the brain. The aim of the present study was to detect reproducible responses to local RF exposure in the parietal cortex of anesthetized rats and to determine their dependence on RF intensity. The target cortex tissue was locally exposed to 2-GHz RF using a figure-eight loop antenna within a range of averaged specific absorption rates (10.5, 40.3, 130, and 263 W/kg averaged over 4.04 mg) in the target area. Local cerebral blood flow (CBF) and temperatures in three regions (target area, rectum, and calf hypodermis) were measured using optical fiber blood flow meters and thermometers during RF exposure. All parameters except for the calf hypodermis temperature increased significantly in exposed animals compared with sham-exposed ones during 18-min exposures. Dependence of parameter values on exposure intensity was analyzed using linear regression models. The elevation of local CBF was correlated with temperature rise in both target and rectum at the end of RF exposure. However, the local CBF elevation seemed to be elevated by the rise in target temperature, but not by that of the rectal temperature, in the early part of RF exposure or at low-intensity RF exposure. These findings suggest that local RF exposure of the rat cortex drives a regulation of CBF accompanied by a local temperature rise, and our findings may be helpful for discussing physiological changes in the local cortex region, which is locally exposed to RF.

Mathur R. Effect of chronic intermittent exposure to AM radiofrequency field on responses to various types of noxious stimuli in growing rats. Electromagn Biol Med. 27(3):266-276, 2008.

There are several reports of altered pain sensation after exposure (from a few minutes to hours in single or repeated doses for 2-3 weeks) to electromagnetic fields (EMF) in adults. The commonly utilized noxious stimulus is radiant heat. The nociceptive responses are known to be influenced by characteristics of stimulus, organism, and environment. We studied the pattern of nociceptive responses to various noxious stimuli in growing rats exposed to radiofrequency field (73.5 MHz amplitude modulated, 16 Hz power density 1.33 mw/cm(2), SAR = 0.4 w/kg) for 45 d (2 h/d). Threshold current for stimulation of nociceptive afferents to mediate motor response of tail (TF), vocalization during stimulus (VD), and vocalization after discharge (VA); the withdrawal latency of tail (TFL) and hind paw (HPL) to thermal noxious stimulus and tonic pain responses were recorded in every rat. The TFL was not affected, HPL was decreased ($p < 0.01$), and the thresholds of TF and VD were not affected, while, that of VA was significantly decreased. The tonic pain rating was decreased ($p < 0.01$). A decrease in the threshold of VA ($p <0.01$) is indicative of an increase in the emotional component of the response to the phasic pain, whereas a decrease in the pain rating indicates analgesia in response to the tonic pain. The results of our study suggest that chronic (45 d), intermittent (2 h/d) amplitude modulated RF field exposure to the peripubertal rat increases the emotional component of phasic pain over a basal eaualgesic state, while late response to tonic pain is decreased. <u>The data suggest that amplitude modulated RF field differentially affects the mechanisms involved in the processing of various noxious stimuli.</u>

Michelozzi P, Capon A, Kirchmayer U, Forastiere F, Biggeri A, Barca A, Perucci CA. Adult and childhood leukemia near a high-power radio station in Rome, Italy. Am J Epidemiol 155(12):1096-1103, 2002.

Some recent epidemiologic studies suggest an association between lymphatic and hematopoietic cancers and residential exposure to high-frequency electromagnetic fields (100 kHz to 300 GHz) generated by radio and television transmitters. Vatican Radio is a very powerful station located in a northern suburb of Rome, Italy. In the 10-km area around the station, with 49,656 residents (in 1991), leukemia mortality among adults (aged >14 years; 40 cases) in 1987-1998 and childhood leukemia incidence (eight cases) in 1987-1999 were evaluated. The risk of childhood leukemia was higher than expected for the distance up to 6 km from the radio station (standardized incidence rate = 2.2, 95% confidence interval: 1.0, 4.1), and there was a significant decline in risk with increasing distance both for male mortality ($p = 0.03$) and for childhood leukemia ($p = 0.036$). The study has limitations because of the small number of cases and the lack of exposure data. <u>Although the study adds evidence of an excess of leukemia in a population living near high-power radio transmitters, no causal implication can be drawn.</u> There is still insufficient scientific knowledge, and new epidemiologic studies are needed to clarify a possible leukemogenic effect of residential exposure to radio frequency radiation.

Mickley GA, Cobb BL, Mason PA, Farrell S, Disruption of a putative working memory task and selective expression of brain c-fos following microwave-induced hyperthermia. Physiol Behav 55(6):1029-1038, 1994.

To discern the effects of hyperthermia on working memory, we recorded the ability of rats to discriminate between objects following microwave radiation exposure. Memory changes were evaluated by measuring relative exploration time of a familiar vs. a new stimulus object. A subject that extensively reexplores a stimulus with which it has previous experience is presumed to exhibit memory loss associated with that object. Between training and testing, rats were exposed to various doses of microwave radiation, were sham irradiated, or remained in their home cage. Brain (dural) and rectal temperatures were recorded. To discern brain regions activated or possibly damaged by microwave exposure, we also used immunocytochemistry techniques to identify sites of c-fos protein expression in the brains of several irradiated/sham-irradiated subjects. Rats exposed to > 5 W/kg exhibited hyperthermia when compared to nonirradiated controls. Normothermic control subjects (sham-irradiated rats and rats exposed to 0.1 W/kg) showed a distinct preference for the new object although other microwave-exposed rats (1, 5, 8.5, 9.3, 10 W/kg) did not. Microwave hyperthermia evoked prominent c-fos expression in periventricular strata, hypothalamic nuclei, amygdala, and several areas of the cortex. These data suggest that performance on a putative working memory task may be disrupted by a sufficiently intense microwave-induced hyperthermia. The pattern of expression of the early proto-oncogene c-fos may suggest candidate brain nuclei that mediate the behavioral changes we observed.

Mickley GA, Cobb BL, Thermal tolerance reduces hyperthermia-induced disruption of working memory: a role for endogenous opiates? Physiol Behav 63(5):855-865, 1998.

Previous reports indicate that microwave-induced hyperthermia can impair learning and memory. Here, we report that preexposure to a single 20-min period of hyperthermia can produce thermal tolerance and, thereby, attenuate future physiological and behavioral reactions to heating. Because endogenous opioids have been implicated in thermoregulation and reactions to microwave exposure, we also determined how opioid receptor antagonism might modulate these effects. In an initial experiment, rats were exposed daily, over 5 successive days, to 600-MHz microwaves (at a whole-body specific absorption rate of 9.3 W/kg) or sham exposed. In animals exposed to microwaves, thermal tolerance was evidenced by declining rectal temperatures over time. Temperature reductions following microwave exposure were prominent after a single previous exposure. Therefore, in a second study, a single hyperthermic episode was used to induce thermal tolerance. On Day 1, rats were either exposed, over a 20-min period, to 600-MHz microwaves (at a whole-body specific absorption rate of 9.3 W/kg) or sham exposed. Just prior to radiation/sham-radiation treatment, rats received either saline or naltrexone (0.1 or 10 mg/kg, intraperitoneally (i.p.)). The following day (Day 2), rats were either microwave or sham exposed and tested on a task which measures the relative time subjects explore a familiar versus a novel stimulus object. Normothermic rats spend significantly more time in contact with new environmental components and less time with familiar objects. Brain (dura) and rectal temperatures were recorded on both days of the study. Microwave exposure produced a reliable hyperthermia which was significantly lower (on Day 2) in rats receiving repeated treatments (tolerant group). On the behavioral test, rats exposed only once to microwave-induced hyperthermia (nontolerant group) exhibited significantly different patterns of object discrimination than did tolerant or sham-exposed animals. Sham-exposed and tolerant animals showed a distinct preference for the new object whereas the nontolerant animals did not. Naltrexone (10 mg/kg) antagonized the hyperthermia-induced disruption of the object discrimination task (in nontolerant rats) and produced patterns of object exploration that were similar to those of sham-irradiated and thermal-tolerant rats, suggesting that endogenous opioids play a role in the organism's response to heating. Taken together, these data are consistent with the conclusions that 1) microwave-induced hyperthermia can cause a dose-dependent disruption of the normal discrimination between new and familiar objects, 2) physiological reactions to a single hyperthermic episode can produce a thermotolerance that expresses itself in both reduced levels of hyperthermia and attenuated behavioral disruptions following microwave exposure, and 3) opioid antagonism can partially reverse some of the behavioral effects of microwave-induced hyperthermia.

Millenbaugh NJ, Roth C, Sypniewska R, Chan V, Eggers JS, Kiel JL, Blystone RV, Mason PA. gene expression changes in the skin of rats induced by prolonged 35 GHz millimeter-wave exposure. Radiat Res 169(3):288-300, 2008.

To better understand the cellular and molecular responses to overexposure to millimeter waves, alterations in the gene expression profile and histology of skin after exposure to 35 GHz radiofrequency radiation were investigated. Rats were subjected to sham exposure, to 42 degrees C environmental heat, or to 35 GHz millimeter waves at 75 mW/cm(2). Skin samples were collected at 6 and 24 h after exposure for Affymetrix GeneChip analysis. The skin was harvested from a separate group of rats at 3-6 h or 24-48 h after exposure for histopathology analysis. Microscopic findings observed in the dermis of rats exposed to 35 GHz millimeter waves included aggregation of neutrophils in vessels, degeneration of stromal cells, and breakdown of collagen. Changes were detected in 56 genes at 6 h and 58 genes at 24 h in the millimeter-wave-exposed rats. Genes associated with regulation of transcription, protein folding, oxidative stress, immune response, and tissue matrix turnover were affected at both times. At 24 h, more genes related to extracellular matrix structure and chemokine activity were altered. Up-regulation of Hspa1a, Timp1, S100a9, Ccl2 and Angptl4 at 24 h by 35 GHz millimeter-wave exposure was confirmed by real-time RT-PCR. These results obtained from histopathology, microarrays and RT-PCR indicate that prolonged exposure to 35 GHz millimeter waves causes thermally related stress and injury in skin while triggering repair processes involving inflammation and tissue matrix recovery.

Mjøen G, Saetre DO, Lie RT, Tynes T, Blaasaas KG, Hannevik M, Irgens LM. Paternal occupational exposure to radiofrequency electromagnetic fields and risk of adverse pregnancy outcome. Eur J Epidemiol. 21(7):529-535, 2006

BACKGROUND: During the last decades, public concern that radiofrequency radiation (RFR) may be related to adverse reproductive outcomes has been emerging. Our objective was to assess associations between paternal occupational exposure to RFR and adverse pregnancy outcomes including birth defects using population-based data from Norway. METHODS: Data on reproductive outcomes derived from the Medical Birth Registry of Norway were linked with data on paternal occupation derived from the general population censuses. An expert panel categorized occupations according to exposure. Using logistic regression, we analyzed 24 categories of birth defects as well as other adverse outcomes. RESULTS: In the offspring of fathers most likely to have been exposed, increased risk was observed for preterm birth (odds ratio (OR): 1.08, 95% confidence interval (CI): 1.03, 1.15). In this group we also observed a decreased risk of cleft lip (OR: 0.63, 95% CI: 0.41, 0.97). In the medium exposed group, we observed increased risk for a category of "other defects" (OR: 2.40, 95% CI: 1.22, 4.70), and a decreased risk for a category of "other syndromes" (OR: 0.75, 95% CI: 0.56, 0.99) and upper gastrointestinal defects (OR: 0.61, 95% CI: 0.40, 0.93). CONCLUSION: The study is partly reassuring for occupationally exposed fathers.

Moneda AP, Ioannidou MP, Chrissoulidis DP. Radio-wave exposure of the human head: analytical study based on a versatile eccentric spheres model including a brain core and a pair of eyeballs. IEEE Trans Biomed Eng. 50(6):667-676, 2003.

A versatile eccentric-spheres model of the human head is used in this paper to investigate radio-wave absorption. Numerical results, obtained by use of an exact analytical solution, are presented for the total, percentage, and gram-specific absorption. Interest is mainly in the brain and in the eyes of an adult or an infant head. Our model comprises a host sphere and several spherical inclusions, all concentrically stratified with respect to their own center. Any number of inclusions and any number of concentric layers for the host sphere and each one of the inclusions can be considered. Excitation is provided either by a plane-wave or by a nearby electric dipole. The analytical solution is obtained by use of the indirect-mode matching method. The theory of this paper and the accompanying computer code constitute a versatile tool for analytical studies of cellular-phone interactions with the human head. Specific absorption rate maps in a horizontal cross section of the head model manifest the existence of hot spots in the eyes and near the center of the brain.

Mortazavi SM, Vazife-Doost S, Yaghooti M, Mehdizadeh S, Rajaie-Far A. Occupational exposure of dentists to electromagnetic fields produced by magnetostrictive cavitrons alters the serum cortisol level. J Nat Sci Biol Med. 3(1):60-64, 2012.

OBJECTIVES: Some studies indicate that dentistry is one of the job categories with high potential exposure to elevated levels of extremely low frequency magnetic fields. In spite of this, information on occupational exposure of dentists to these fields is scarce. Studies on other common sources of electromagnetic fields (EMFs) such as mobile base stations have shown alterations in the cortisol level following exposure of humans to these sources. The aim of this study is to compare the level of cortisol among dentists and dentistry students who are being occupationally exposed to EMFs emitted by magnetostrictive cavitrons (case group) and among their counterparts who are not being exposed to these fields (control group). MATERIALS AND METHODS: In this case-control study, blood samples were collected from 41 dentists and dentistry students, 21 of whom were exposed to EMFs emitted by cavitrons as the case group and 20 who were not exposed as the control group, twice; i.e. before work (at 8:30-9:30 a.m.) and after work (11:30-12:30 a.m.). The samples were coded and the serum cortisol level was investigated using the ELISA method (Cortisol AccuBind ELISA Kits). RESULTS: The serum cortisol level of dentists and dental students in the morning (before starting the work) in the control group was 189.15 ± 110.70 (mean ± SD) whereas it was 157.77 ± 112.03 in those who were occupationally exposed to EMFs produced by the use of cavitrons. This difference was not statistically significant (P = 0.373). In contrast, the serum cortisol level of the participants in the noon (after stopping the work) in the control group was 136.25 ± 67.91 (mean ± SD) while it was 88.58 ± 52.83 in those who were occupationally exposed to EMFs produced by the use of cavitrons. This time, the observed difference was statistically significant (P = 0.016). In this light, while the difference between serum cortisol levels of dentists and dental students in the morning and after stopping the work was not statistically significant (P = 0.06), in the EMF-exposed group the cortisol level decreased significantly from 157.77 ± 112.03 in the morning to 88.58 ± 52.83 in the noon (P = 0.001).CONCLUSIONS: As far as we know, this is the first study that evaluated the effect of occupational exposure of dentists to EMFs on their serum cortisol level. <u>The EMFs produced by magnetostrictive cavitrons can decrease the serum cortisol level in dentists. As cortisol plays an important role in blood pressure regulation, cardiovascular, and immune system function, a low cortisol level may threaten health.</u> More studies are needed to clearly understand the effects of EMFs emitted by magnetostrictive cavitron on the level of stress hormones. As some studies have shown that exposure to EMFs has no effect on the cortisol level, whereas other studies reported either an increase or a decrease in the cortisol level, it can be concluded that the effects of exposure to EMFs may occur only at specific absorbed energies or energy absorption rates (usually known as window) similar to that exists in the case of exposure to the low doses of ionizing radiations.

Mortazavi SM, Taeb S, Dehghan N. Alterations of visual reaction time and short term memory in military radar personnel. Iran J Public Health. 42(4):428-435, 2013.

BACKGROUND: Radar transmitters emit high-power radiofrequency radiation by creation of a high-voltage and high-frequency alternating electrical current. METHODS: Health effects of occupational exposure to military radar were investigated. Visual reaction time was recorded with a simple blind computer-assisted-visual reaction time test. To assess the short-term memory, modified Wechsler Memory Scale test was performed. RESULTS: The mean +/- SD reaction time in radar works (N=100) and the control group (N=57) were 238.58 +/- 23.47

milliseconds and 291.86 +/- 28.26 milliseconds (P<0.0001), respectively. The scores of forward digit span in radar works and the control group were 3.56 +/- 0.77 and 4.29 +/- 1.06 (P<0.0001), while the scores of backward digit span in radar works and the control group were 2.70 +/- 0.69 and 3.62 +/- 0.95 (P<0.0001). The scores of word recognition in radar works and the control group were 3.37 +/- 1.13 and 5.86 +/- 1.11 (P<0.0001). Finally, the scores of paired words in radar works and the control group were 13.56 +/- 1.78 and 15.21 +/- 2.20 (P<0.0001). It can be concluded that occupational exposures to radar radiations decreases reaction time, which may lead to a better response to different hazards. CONCLUSION: To the best of our knowledge, this is the first study to show that occupational exposure to radar microwave radiation leads to decreased reaction time and the lower performance of short-term memory. Altogether, these results indicate that occupational exposure to radar microwave radiations may be linked to some non-detrimental and detrimental health effects.

Monselise EB, Levkovitz A, Gottlieb HE, Kost D. Bioassay for assessing cell stress in the vicinity of radio-frequency irradiating antennas. J Environ Monit. 13(7):1890-1896, 2011.

The 24 h exposure of water plants (etiolated duckweed) to RF-EMF between 7.8 V m(-1) and 1.8 V m(-1), generated by AM 1.287 MHz transmitting antennas, resulted in alanine accumulation in the plant cells, a phenomenon we have previously shown to be a universal stress signal. The magnitude of the effect corresponds qualitatively to the level of RF-EMF exposure. In the presence of 10 mM vitamin C, alanine accumulation is completely suppressed, suggesting the involvement of free radicals in the process. A unique biological connection has thus been made between exposure to RF-EMF and cell stress, in the vicinity of RF transmitting antennas. This simple test, which lasts only 24 h, constitutes a useful bioassay for the quick detection of biological cell stress caused in the vicinity of RF irradiating antennas.

Morrissey JJ, Raney S, Heasley E, Rathinavelu P, Dauphinee M, Fallon JH, IRIDIUM exposure increases c-fos expression in the mouse brain only at levels which likely result in tissue heating. Neuroscience 92(4):1539-1546, 1999.

With the rapid development of wireless communication technology over the last 20 years, there has been some public concern over possible health effects of long-term, low-level radiofrequency exposure from cellular telephones. As an initial step in compiling a database for risk analysis by government agencies, the effects of 1-h exposure of mice to a 1.6-GHz radiofrequency signal, given as either a continuous wave or pulse modulated at 11 Hz with a duty cycle of 4:1 and a pulse duration of 9.2 ms IRIDIUM), on c-fos gene expression in the brain was investigated. The IRIDIUM signal is the operating frequency for a ground-to-satellite-to-ground cellular communications web which has recently become fully operational, and was named as such due to the original designed employment of the same number of low orbiting satellites as there are electrons orbiting the nucleus of an iridium atom. The expression of c-fos was not significantly elevated in the brains of mice until exposure levels exceeded six times the peak dose and 30 times the whole body average dose as maximal cellular telephone exposure limits in humans. Higher level exposure using either continuous wave (analog) or IRIDIUM signals elevated c-fos to a similar extent, suggesting no obvious pulsed modulation-specific effects. The pattern of c-fos elevation in limbic cortex and subcortex areas at higher exposure levels is most consistent with a stress response due to thermal perception coupled with restraint and/or neuron activity near thermoregulatory regions, and not consistent with any direct interaction of IRIDIUM energy with brain tissue.

Moszczynski P, Lisiewicz J, Dmoch A, Zabinski Z, Bergier L, Rucinska M, Sasiadek U, [The effect of various occupational exposures to microwave radiation on the concentrations of immunoglobulins and T lymphocyte subsets]. Wiad Lek 52(1-2):30-34, 1999. [Article in Polish]

The immunoglobulins' concentrations and T lymphocyte subsets during occupational exposures to microwave radiation were assessed. In the workers of retransmission TV center and center of satellite communications on increased IgG and IgA concentration and decreased count of lymphocytes and T8 cells was found. However, in the radar operators IgM concentration was elevated and a decrease in the total T8 cell count was observed. The different behaviour of examined immunological parameters indicate that the effect of microwave radiation on immune system depends on character of an exposure. Disorders in the immunoglobulins' concentrations and in the T8 cell count did not cause any clinical consequences.

Musaev AV, Ismailova LF, Gadzhiev AM. [Influence of (460 MHz) electromagnetic fields on the induced lipid peroxidation in the structures of visual analyzer and hypothalamus in experimental animals] Vopr Kurortol Fizioter Lech Fiz Kult. (5):17-20, 2005. [Article in Russian]

Changes in the intensity of ascorbate- and NADPN2-dependent induced lipid peroxidation (LPO) were studied in exposure of the visual analyzer and hypothalamus of 3- and 12-month-old rats to radiation with microwaves of high and low intensity. The exposure to microwaves of high intensity stimulated basal LPO but suppressed activity of LPO-inducing systems. This suggests disturbances in the activity of different sources of active oxygen forms. Microwaves of low intensity activated systems of induced LPO. This is accompanied with synchronous activity of the antioxidant defense system maintaining a normal oxidation-reduction balance of the cell. The conclusion is that, depending on their intensity, microwaves can be either beneficial to health or be a factor of oxidative stress.

Nageswari KS, Sarma KR, Rajvanshi VS, Sharan R, Sharma M, Barathwal V, Singh V, Effect of chronic microwave radiation on T cell-mediated immunity in the rabbit. Int J Biometeorol 35(2):92-97, 1991.

Experiments were conducted to elucidate the effects of chronic low power-level microwave radiation on the immunological systems of rabbits. Fourteen male Belgian white rabbits were exposed to microwave radiation at 5 mW/cm2, 2.1 GHz, 3 h daily, 6 days/week for 3 months in two batches of 7 each in specially designed miniature anechoic chambers. Seven rabbits were subjected to sham exposure for identical duration. The microwave energy was provided through S band standard gain horns connected to a 4K3SJ2 Klystron power amplifier. The first batch of animals were assessed for T lymphocyte-mediated cellular immune response mechanisms and the second batch of animals for B lymphocyte-mediated humoral immune response mechanisms. The peripheral blood samples collected monthly during microwave/sham exposure and during follow-up (5/14 days after termination of exposures, in the second batch animals only) were analysed for T lymphocyte numbers and their mitogen responsiveness to ConA and PHA. Significant suppression of T lymphocyte numbers was noted in the microwave group at 2 months (P less than 0.01, delta % 21.5%) and during follow-up (P less than 0.01, delta % 30.2%). The first batch animals were initially sensitised with BCG and challenged with tuberculin (0.03 ml) at the termination of microwave irradiation/sham exposure and the increase in foot pad thickness (delta mm), which is a measure of T cell-mediated immunity (delayed type hypersensitivity response, DTH) was noted in both the groups. The microwave group revealed a better response than the control group (delta % +12.4 vs. +7.54). The animals were sacrificed and the tissue T lymphocyte counts (spleen and lymph node) were analysed.

Nakamura, H, Seto, T, Hatta, K, Matsuzaki, I, Nagase, H, Yoshida, M, Ogino, K, Natural killer cell activity reduced by microwave exposure during pregnancy is mediated by opioid systems. Environ Res 79(2):106-113, 1998.

We have previously demonstrated immunosuppression including reduced splenic natural killer cell activity (NKCA) in pregnant rats exposed to microwaves produced mainly by their thermal action. To examine the involvement of opioid systems in reduced NKCA in pregnant rats exposed to microwaves at a relatively low level (2 mW/cm2 incident power density at 2450 MHz for 90 min), we assayed beta-endorphin (betaEP) in blood, pituitary lobes, and placenta as well as splenic NKCA in virgin and/or pregnant rats. Although microwaves elevated colonic temperatures by 0.8 degreesC for virgin and 0.9 degreesC for pregnant rats, and betaEP in blood and anterior pituitary lobes (AP) significantly, it did not change blood corticosterone as an index of hypothalamic-pituitary adrenal axis. There were significant interactions between pregnancy and microwave exposure on splenic NKCA, betaEP in both blood and AP, and blood progesterone. Intra-peritoneal administration of opioid receptor antagonist naloxone prior to microwave exposure increased NKCA, blood, and placental betaEP in pregnant rats. Alterations in splenic NKCA, betaEP and progesterone in pregnant rats exposed to microwaves may be due to both thermal and nonthermal actions. These results suggest that NKCA reduced by microwaves during pregnancy is mediated by the pituitary opioid system.

Nakamura H, Nagase H, Ogino K, Hatta K, Matsuzaki I, Uteroplacental circulatory disturbance mediated by prostaglandin F(2alpha) in rats exposed to microwaves. Reprod Toxicol 14(3):235-240, 2000.

To clarify the effects of microwaves on pregnancy, uterine or uteroplacental blood flow and endocrine and biochemical mediators, including corticosterone, estradiol, prostaglandin E(2) (PGE(2)), and prostaglandin F(2)alpha (PGF(2)alpha), were measured in rats exposed to continuous-wave (CW) microwave at 2 mW/cm(2) incident power density at 2450 MHz for 90 min. Colonic temperature in virgin and pregnant rats was not significantly altered by microwave treatment. Microwaves decreased uteroplacental blood flow and increased progesterone and PGF(2)alpha in pregnant, but not in virgin rats. Intraperitoneal (i.p.) administration of angiotensin II, a uteroplacental vasodilator, before microwave exposure prevented the reduction in uteroplacental blood flow and the increased progesterone and PGF(2)alpha in pregnant rats. Increased corticosterone and decreased estradiol during microwave exposure were observed independent of pregnancy and pretreatment with angiotensin II. These results suggest that microwaves (CW, 2 mW/cm(2), 2450 MHz) produce uteroplacental circulatory disturbances and ovarian and placental dysfunction during pregnancy, probably through nonthermal actions. The uteroplacental disturbances appear to be due to actions of PGF(2)alpha and may pose some risk for pregnancy.

Narasimhan V, Huh WK, Altered restriction patterns of microwave irradiated lambdaphage DNA. Biochem Int 25(2):363-370, 1991.

Samples of lambdaphage DNA exposed to short pulses of microwave irradiation were subjected to restriction fragmentation by Eco RI and Bam HI. Eco RI digests of microwaved DNA samples yielded three additional fragments ranging in base pair lengths between 24,226 and 7,421 besides the six expected fragments. While Bam HI digests of the microwaved samples did not yield any additional fragments, mobilities of the Bam HI fragments from the microwaved DNA samples were slower and the bands were broader in comparison to those from native samples. We attribute these altered restriction patterns to the conformational anomolies in DNA resulting from single strand breaks and localized strand separations induced by microwave irradiation.

Nasri K, Daghfous D, Landoulsi A. Effects of microwave (2.45 GHz) irradiation on some biological characters of Salmonella typhimurium. C R Biol. 2013 Apr;336(4):194-202.

The present study was carried out to evaluate the effects of sub-lethal doses of microwave radiation on some biological characteristics in Salmonella typhimurium. The aim was to show the relationship between this treatment and the development of radiotolerance in this pathogen because there is a need for more information on physiological responses of pathogens to sub-lethal doses of microwave radiation. So, the bacterial strain was treated with a dose of 3600J (40-s exposure with power P=90 W) to cause cellular damage. The results have shown that the exposure of bacteria to microwaves resulted in a significant inhibition of cellular growth. This treatment has notably increased the effectiveness of the most tested antibiotics by the amelioration or the appearance of sensitivity in exposed bacteria. Gas chromatography (GC) analysis was performed to demonstrate the modification of the fatty acids (FA) composition. Results obtained have shown that this treatment had a significant effect on the FA content with an increase of unsaturated FA percentage. The acquisition of sensitivity to the sodium deoxycholate and the significant increase in the amount of extracellular proteins in exposed bacteria has confirmed the weakening of the bacterial membrane by microwaves. This study represents one of the few demonstrating the modifications on the bacterial membrane as a cellular response to survive the non-ionising radiation stress.

Natarajan M, Vijayalaxmi , Szilagyi M, Roldan FN, Meltz ML. NF-κB DNA-binding activity after high peak power pulsed microwave (8.2 GHz) exposure of normal human monocytes. Bioelectromagnetics 23:271-277, 2002.

The hypothesis investigated is that exposure of a mammalian cell to high peak power pulsed RF, at the frequency of 8.2 GHz, can result in the activation of an important eukaryotic transcriptional regulator, nuclear factor kappa B (NF-κB). This DNA-binding protein controls genes involved in long term cellular regulation. The selection of 8.2 GHz was based on the availability of a high peak power pulsed RF transmitter. In these studies, triplicate cultures of human monocytes (Mono Mac-6) were exposed to the pulsed wave radiation. The peak to average power ratio was 455:1 (2.2 μs pulse width and pulse repetition rate of 1000 pulses/s). The average power density at the position of exposure was 50 W/m^2, and the mean SAR at the bottom of the culture flask was 10.8 ± 7.1 W/kg. The FDTD analysis indicated that 10% of the cells had an SAR of 22-29 W/kg. The cells were exposed continuously for 90 min at 37 °C, reincubated at this temperature, and harvested 4 h postexposure. The nuclear extracts were analyzed by electrophoretic mobility shift assay. The results showed a profound increase (3.6-fold) in the DNA binding activity of NF-κB in monocytes at 4 h after the pulsed RF exposure compared to sham irradiated controls. Competition experiments with cold NF-κB- specific oligonucleotides confirmed the specificity of the DNA binding activity. These results provide evidence that high peak power pulsed radiofrequency radiation can perturb the cell and initiate cell signaling pathways. However, at this point, we are not prepared to advocate that the cause is a nonthermal mechanism. Because of the broad distribution of SAR's in the flask, experiments need to be performed to determine if the changes observed are associated with cells exposed to high or low SARs.

Natarajan M, Nayak BK, Galindo C, Mathur SP, Roldan FN, Meltz ML. Nuclear translocation and DNA-binding activity of NFKB (NF-kappaB) after exposure of human monocytes to pulsed ultra-wideband electromagnetic fields (1 kV/cm) fails to transactivate kappaB-dependent gene expression. Radiat Res. 165(6):645-654, 2006.

The objective of this study was to investigate whether exposure of human monocytes to a pulsed ultra-wideband electromagnetic field (EMF) of 1 kV/cm average peak power triggers a signaling pathway responsible for the transcriptional regulation of NFKB (NF-kappaB)-dependent gene expression. Human Mono Mac 6 (MM6) cells were exposed intermittently to EMF pulses for a total of 90 min. The pulse width was 0.79+/-0.01 ns and the pulse repetition rate was 250 pps. The temperature of the medium was maintained at 37 degrees C in both sham- and EMF-exposed flasks. Total NFKB DNA-binding activity was measured in the nuclear extracts by the electrophoretic mobility shift assay. Cells exposed to the EMFs and incubated for 24 h postexposure showed a 3.5+/-0.2-fold increase in the NFKB DNA-binding activity. Since activation of NFKB was observed, the possibility of kappaB-dependent gene expression in response to exposure to the EMFs was investigated using NFKB signal-specific gene arrays. The results revealed no difference in the NFKB-dependent gene expression profiles at 8 or 24 h postexposure, indicating that activated NFKB does not lead to the differential expression of kappaB-dependent target genes. To determine whether the absence of the kappaB-dependent gene expression was due to compromised transcriptional regulation of NFKB, the functional activity of NFKB was examined in cells transiently transfected with Mercury Pathway constructs containing 4x NFKB binding sites associated either with the luciferase reporter system or a control vector. Pulsed EMF exposure did not induce NFKB-driven luciferase activity in these cells, indicating that the activation of NFKB at 24 h after the 1 kV/cm EMF exposure is functionally inactive. From these results, it is clear that the EMF-induced NFKB activation is only a transient response, with minimal or no downstream effect.

Navakatikian MA, Tomashevskaya LA, Phasic behavioral and endocrine effects of microwaves of nonthermal intensity. In "Biological Effects of Electric and Magnetic Fields, Volume 1," D.O. Carpenter (ed) Academic Press, San Diego, CA, 1994, pp.333-342.

Microwaves at nonthermal levels are able to induce behavioral and endocrine changes at low power densities (0.01-0.1 mW/cm2). Our studies have demonstrated several phases of inhibition and activation. We suggest that inhibition of behavior by microwaves has many mechanisms depending on the strength and duration of exposure, and most inhibitory effects from direct actions on the nervous system. Activation, on the other hand, is correlated well with decreases in serum concentrations of testosterone and insulin. CW microwaves, however, have no influence on the secretion of insulin.

Novoselova ET, Fesenko EE, [[Stimulation of production of tumor necrosis factor by murine macrophages when exposed in vio and in vitro to weak electromagnetic waves in the centimeter range]]. Biofizika 43(6):1132-1333, 1998. [Article in Russian]

Whole-body microwave sinusoidal irradiation of male NMRI mice, exposure of macrophages in vitro, and preliminary irradiation of culture medium with 8.15-18 GHz (1 Hz within) at a power density of 1 microW/cm2 caused a significant enhancement of tumor necrosis factor production in peritoneal macrophages. The role of microwaves as a factor interfering with the process of cell immunity is discussed.

Novoselova, EG, Fesenko, EE, Makar, VR, Sadovnikov, VB, Microwaves and cellular immunity. II. Immunostimulating effects of microwaves and naturally occurring antioxidant nutrients. Bioelectrochem Bioenerg 49(1):37-41, 1999.

The effect of 8.15-18 GHz (1 Hz within) microwave radiation at a power density of 1 microW/cm2 on the tumor necrosis factor (TNF) production and immune response was tested. A single 5 h whole-body exposure induced a significant increase in TNF production in peritoneal macrophages and splenic T cells. The mitogenic response in T lymphocytes increased after microwave exposure. The activation of cellular immunity was observed within 3 days after exposure. The diet containing lipid-soluble nutrients (beta-carotene, alpha-tocopherol and ubiquinone Q9) increased the activity of macrophages and T cells from irradiated mice. These results demonstrate that irradiation with low-power density microwaves stimulates the immune potential of macrophages and T cells, and the antioxidant treatment enhances the effect of microwaves, in particular at later terms, when the effect of irradiation is reduced.

Novoselova EG, Ogai VB, Sorokina OV, Novikov VV, Fesenko EE., [Effect of centimeter microwaves and the combined magnetic field on the tumor necrosis factor production in cells of mice with experimental tumors]. Biofizika 46(1):131-135, 2001. [Article in Russian]

The effect of fractionated exposure to low-intensity microwaves (8.15-18 GHz, 1 microW/cm2, 1.5 h daily for 7 days) and combined weak magnetic field (constant 65 1 microT; alternating--100 nT, 3-10 Hz) on the production of tumor necrosis factor in macrophages of mice with experimental solid tumors produced by transplantation of Ehrlich ascites carcinoma was studied. It was found that exposure of mice to both microwaves and magnetic field enhanced the adaptive response of the organism to the onset of tumor growth: the production of tumor necrosis factor in peritoneal macrophages of tumor-bearing mice was higher than in unexposed mice.

Ohmoto Y, Fujisawa H, Ishikawa T, Koizumi H, Matsuda T, Ito H, Sequential changes in cerebral blood flow, early neuropathological consequences and blood-brain barrier disruption following radiofrequency-induced localized hyperthermia in the rat. Int J Hyperthermia 12(3):321-334, 1996.

We investigated the temperature distribution, early histological changes, blood brain barrier (BBB) disruption and sequential changes in cerebral blood flow (CBF) following hyperthermia ranging from 37 to 45 degrees C in a new rat model of radiofrequency-induced localized cerebral hyperthermia. Significant histological changes and BBB disruption were observed in brain regions heated to 43 degrees C and above. In the cortex heated to 41 degrees C, the CBF doubled 20 min after hyperthermia induction, and then returned gradually to the pre-hyperthermic level. In the cortex heated to 43 degrees C, the CBF increased to 134% of the baseline level 10 min after hyperthermia induction, and then fell gradually to reach its minimum level (31% of the baseline level). In the cortex heated to 45 degrees C, the CBF decreased immediately after hyperthermia induction to reach 10% of the baseline level. The results indicate that hyperthermia-induced cellular injury in the central nervous system is associated with cerebral ischaemia and the threshold temperature for such injury is 43 degrees C. This model is useful for investigating the effects of hyperthermia on various cerebral functions and the CBF changes demonstrated in the present study may provide key information for the analysis of other cerebral functions.

Olchowik G, Maj JG, Inhibitory action of microwave radiation on gamma-glutamyl transpeptidase activity in liver of rats treated with hydrocortisone. Folia Histochem Cytobiol 38(4):189-191, 2000.

The influence of microwave irradiation on the activity of gamma-glutamyl transpeptidase (GGT) induced by hydrocortisone (HC) in the liver of rats was investigated. Animals were subjected to microwave irradiation (frequency 53.57 GHz, power density 10 mW/cm2 and 1 mW/cm2) during and after hydrocortisone (HC) treatment (20 mg/kg for 60 days). <u>The results indicate that microwave radiation may block an inducible effect of HC on GGT activity in the liver of rats. This effect depends on the power density of millimetre microwaves.</u>

Ouellet-Hellstrom R, Stewart WF, Miscarriages among female physical therapists who report using radio- and microwave-frequency electromagnetic radiation. Am J Epidemiol 138(10):775-786, 1993.

Physical therapists are exposed to radio- and microwave-frequency electromagnetic radiation by operating shortwave and microwave diathermy units. Recent studies suggest that use of shortwave diathermy is associated with an excess risk of birth defects, perinatal deaths, and late spontaneous abortions among the offspring of exposed female therapists. To assess the impact of occupational use of microwave and shortwave diathermy at the time of conception, the authors mailed questionnaires to 42,403 physical therapists in 1989. Both occupational and reproductive histories were obtained. Exposures to shortwave and microwave diathermy were both assessed in the same fashion and were examined in relation to early recognized fetal loss in a nested case-control design. A total of 1,753 case pregnancies (miscarriages) were matched to 1,753 incidence density control pregnancies (other pregnancies except ectopic pregnancies). A pregnancy was considered "exposed" if the mother reported using microwave or shortwave diathermy anytime during the 6 months prior to the first trimester or during the first trimester. <u>Pregnancies of mothers reporting microwave use 6 months prior to the pregnancy or during the first trimester were more likely to result in miscarriage (odds ratio (OR) = 1.28, 95% confidence interval (CI) 1.02-1.59).</u> <u>The odds ratio increased with increasing level of exposure (chi 2 = 7.25, p < 0.005). The odds ratio in the highest exposure group (20 or more exposures/month) was 1.59.</u> The overall odds ratio was slightly lower after it was controlled for prior fetal loss (OR = 1.26, 95% CI 1.00-1.59), but the exposure-response effect remained (chi 2 = 5.17, p < 0.01). The risk of miscarriage was not associated with reported use of shortwave diathermy equipment (OR = 1.07, 95% CI 0.91-1.24). The odds ratio in the highest exposure group was 0.87.

Pakhomov AG, Mathur SP, Doyle J, Stuck BE, Kiel JL, Murphy MR, Comparative effects of extremely high power microwave pulses and a brief CW irradiation on pacemaker function in isolated frog heart slices. Bioelectromagnetics 21(4):245-254, 2000.

The existence of specific bioeffects due to high peak power microwaves and their potential health hazards are among the most debated but least explored problems in microwave biology. The present study attempted to reveal such effects by comparing the bioeffects of short trains of extremely high power microwave pulses (EHPP, 1 micros width, 250-350 kW/g, 9.2 GHz) with those of relatively low power pulses (LPP, 0.5-10 s width, 3-30 W/g, 9.2 GHz). EHPP train duration and average power were made equal to those of an LPP; therefore both exposure modalities produced the same temperature rise. Bioeffects were studied in isolated, spontaneously beating slices of the frog heart. In most cases, a single EHPP train or LPP immediately decreased the inter-beat interval (IBI). The effect was proportional to microwave heating, fully reversible, and easily reproducible. The magnitude and time course of EHPP- and LPP-induced changes always were the same. No delayed or irreversible effects of irradiation were observed. The same effect could be repeated in a single preparation numerous times with no signs of adaptation, sensitization, lasting functional alteration, or damage. A qualitatively different effect, namely, a temporary arrest of preparation beats, could be observed when microwave heating exceeded physiologically tolerable limits. This effect also did not depend on whether the critical temperature rise was produced by LPP or EHPP exposure. Within the studied limits, we found no indications of EHPP-specific bioeffects. EHPP- and LPP-induced changes in the pacemaker rhythm of isolated frog heart preparation were identical and could be entirely attributed to microwave heating.

Pakhomov AG, Gajšek P, Allen L, Stuck BE, Murphy MR. Comparison of dose dependences for bioeffects of continuous-wave and high-peak power microwave emissions using gel-suspended cell cultures. Bioelectromagnetics 23: 158-167, 2002.

The study compared bioeffects of continuous wave (CW) microwaves and short, extremely high power pulses (EHPP) at the same carrier frequency (9.3 GHz) and average power (1.25 W). The peak transmitted power for EHPP was 250 kW (0.5-μs pulse width, 10 p.p.s.), producing the E field of 1.57 MV/m in the waveguide. A biological endpoint was the density of yeast cells, achieved after a 6 h growth period in a solid nutrient medium (agarose gel) during EHPP or CW exposure. Owing to power losses in the medium, the specific absorption rate (SAR) ranged from 3.2 kW/kg at the exposed surface of the sample to 0.6 mW/kg at 24 mm depth. Absorption and penetration of EHPP was identical to CW, producing peak SAR values 200 000 times higher than the average SAR, as high as 650 MW/kg at the surface. CW and EHPP exposures produced highly nonuniform but identical heating patterns in exposed samples. Following the exposure, the samples were sliced in a plane perpendicular to the wave propagation, in order to separate cell masses exposed at different SAR levels. Cell density in the slices was determined by nephelometry and compared to unexposed parallel control samples. Cell density was strongly affected by irradiation, and the changes correlated well with the local temperature rise. However, the data revealed no statistically significant difference between CW and EHPP samples across the entire studied range of SAR levels (over six orders of magnitude). A trend ($P < 0.1$) for such a difference was observed in slices that were exposed at a time average SAR of 100 W/kg and higher, which corresponded to peak SAR above 20 MW/kg for the EHPP condition. These numbers could be indicative of a threshold for a specific (not merely thermal) exposure effect if the trend is confirmed by future studies.

Palfia Z, Somosy Z, Rez G. Tight junctional changes upon microwave and x-ray irradiation. Acta Biol Hung 52(4):411-416, 2001.

Tight junctions (zonulae occludentes, ZO) are cellularly regulated dynamic structures sensitive to environmental stress agents including ionizing radiation. Radiation induced pathological alterations of the small intestine (gastrointestinal radiation syndrome) are related to altered ZO-mediated paracellular transport. We carried out a quantitative morphological evaluation of the murine jejunal epithelial tight junctional structure in freeze fracture replicas as changed upon whole body X-ray irradiation and low energy microwave exposition. X-ray treatment (4 Gy, 1, 24 h) brought about a partial dearrangement of the ZO strand network which regenerated only partially by 24 h. This observation is in line with data on paracellular permeability increases and ZO-bound calcium drop caused by X-ray irradiation. On the other hand, microwave treatment (16 Hz-modulated 2.45 GHz wave, 1 mW/cm2 power density, I h exposition, samples at I and 3 h after exposition) did not cause dearrangement but, rather an increase in the integration of thight junctional structure, which is in agreement with an increase in cytochemically detectable ZO-bound calcium.

Park SK,Ha M, Im H-J.Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea. Int Arch Occup Environ Health 77(6):387-394, 2004.

Abstract. Objectives Public health concern about the health effects of radio-frequency electromagnetic fields (RF-EMFs) has increased with the increase in public exposure. This study was to evaluate some health effect of RF exposure by the AM radio broadcasting towers in Korea. Methods We calculated cancer mortality rates using Korean death certificates over the period of 1994–1995 and population census data in ten RF-exposed areas, defined as regions that included AM radio broadcasting towers of over 100 kW, and in control areas, defined as regions without a radio broadcasting tower inside and at least 2 km away from the towers. Results All cancers-mortality was significantly higher in the exposed areas [direct standardized mortality rate ratio (MRR) =1.29, 95%CI=1.12–1.49]. When grouped by each exposed area and by electrical power, MRRs for two sites of 100 kW, one site of 250 kW and one site of 500 kW, for all subjects, and for one site of 100 kW and two sites of 250 kW, for male subjects, showed statistically significant increases without increasing trends according to the groups of electric power. Leukemia mortality was higher in exposed areas (MRR=1.70, 95% CI=0.84–3.45), especially among young adults aged under 30 years (0–14 years age group, MRR=2.29, 95% CI=1.05–5.98; 15–29 age group, MRR=2.44, 95% CI=1.07–5.24) . Conclusions We observed higher mortality rates for all cancers and leukemia in some age groups in the area near the AM radio broadcasting towers. Although these findings do not prove a causal link between cancer and RF exposure from AM radio broadcasting towers, it does suggest that further analytical studies on this topic are needed in Korea.

Pashovkina MS, Akoev IG. [Effect of low intensity pulse-modulated electromagnetic radiation on activity of alkaline phosphatase in blood serum]. Radiats Biol Radioecol 41(1):62-66, 2001. [Article in Russian]

The change in alkaline phosphotase activity in vitro with frequencies modulation at low intensity of pulse-modulated electromagnetic radiation was experimentally shown (EMR, 2375 MHz, intensity: 0.8, 8.0; 40.0 microW/cm2; range modulation: 30-310 Hz; time of interaction: 1-3 min). Revealed effects could be regarded as an evidence of informative character of interaction of modulated EMR.

Pashovkina MS, Akoev IG. [Effect of low-intensity pulse-modulated microwave on human blood aspartate aminotransferase activity]. Radiats Biol Radioecol 41(1):59-61, 2001. [Article in Russian]

Pulse-modulated microwaves (frequency 2375 MHz, intensity: 2 microW/cm2 and 8 microW/cm2, pulse modulation from 50 to 390 Hz with step of 20 Hz; exposure time 5 min) changed the activity of aspartataminotranspherase of the donor blood. Aspartataminotranspherase activity was strongly dependent both on modulation frequency and microwave intensity. Maximum activity was found at 390 Hz and 8 microW/cm2. Maximum observed activity was about six times greater than control level of activity.

Pashovkina MS, Akoev IG, [Changes in serum alkaline phosphatase activity during in vitro exposure to amplitude-modulated electromagnetic field of ultrahigh frequency (2375 MHz) in guinea pigs]. Biofizika 45(1):130-136, 2000. [Article in Russian]

The activity of alkaline phosphatase by the action of pulse-modulated microwave radiation was studied. The carrier frequency of radiation was 2375 MHz, the range of modulation pulse rate was 10-390 Hz with the on-off time ratio 2, and the specific absorption rate was 8 and 0.8 microW/cm2. Time of exposure was 1 and 3 min under conditions of continuous temperature control. It was shown that the activity of alkaline phosphatase depends on both modulation frequency and intensity of superhigh-frequency electromagnetic radiation. At a frequency of 70 Hz, the activity of alkaline phosphatases increased 1.8-2.0 times.

Pashovskina MS, Akoev IG, [Effects of 2375 MHz pulse-modulated microwave radiation on ATPase activity of the rat muscle actomyosin]. Radiats Biol Radioecol 36(5):700-705, 1996. [Article in Russian]

Solution of rat muscle actomyosin (AM) was exposed to pulse-modulated microwave. Carried frequency was 2375 MHz. The rectangular pulse modulation was
in the range of 50-300 pulses per second. It was shown that AM activity was dependent both on modulation frequency as well as on microwave intensity. It was shown the frequencies of modulation which were changed ATP-ase activity of AM.

Paul Raj R, Behari J, Rao AR, Effect of amplitude modulated RF radiation on calcium ion efflux and ODC activity in chronically exposed rat brain. Indian J Biochem Biophys 36(5):337-340, 1999.

The effect of exposing rats to amplitude modulated radiofrequency radiation (112 MHz modulated to 16 Hz) during development and growth has been examined. <u>Wistar rats (35 days old) when exposed at above frequency at the power level 1.0 mW/cm2 (SAR, 0.75 W/kg) for 35 days showed enhanced ornithine decarboxylase activity and Ca2+ efflux in brain indicating potential health hazards due to exposure.</u>

Paulraj R, Behari J. Radio frequency radiation effects on protein kinase C activity in rats' brain. Mutat Res. 545(1-2):127-130, 2004.

The present work describes the effect of amplitude modulated radio frequency (rf) radiation (112 MHz amplitude-modulated at 16 Hz) on calcium-dependent protein kinase C (PKC) activity on developing rat brain. Thirty-five days old Wistar rats were used for this study. The rats were exposed 2 h per day for 35 days at a power density of 1.0 mW/cm2 (SAR = 1.48 W/kg). After exposure, rats were sacrificed and PKC was determined in whole brain, hippocampus and whole brain minus hippocampus separately. <u>A significant decrease in the enzyme level was observed in the exposed group as compared to the sham exposed group. These results indicate that this type of radiation could affect membrane bound enzymes associated with cell signaling, proliferation and differentiation. This may also suggest an affect on the behavior of chronically exposed rats.</u>

Pavel A, Ungureanu CE, Bara II, Gassner P, Creanga DE, [Cytogenetic changes induced by low-intensity microwaves in the species Triticum aestivum]. Rev Med Chir Soc Med Nat Iasi 102(3-4):89-92, 1998. [Article in Romanian]

Seeds of Triticum aestivum having an uniform genophond have been exposed to a microwave flow, with a frequency of 9.75 GHz and a low intensity. The effects of microwaves at various doses on mitotic activity have been followed. Our results show that as compared to the controls different types of chromosomal aberrations appeared: delayed chromosomes, micronuclei, interchromosomal bridges, chromosomal fragments.

Pavicic I, Trosic I, Sarolic A**. Comparison of 864 MHz and 935 MHz microwave radiation effects on cell culture.** Arh Hig Rada Toksikol. **57(2):149-154, 2006.**

The objective of this study was to compare the effects of 864 MHz and 935 MHz radiofrequency/microwave radiation on the ability of V79 cells to proliferate, form colonies and on their viability. For one, two and three hours, the cells were exposed to the 864 MHz field in a transversal electromagnetic mode cell (TEM) connected with amplifier and to the 935 MHz field in a gigahertz transversal electromagnetic mode cell (GTEM) equipped with a signal generator. The average specific absorption rate (SAR) was 0.08 W kg(-1) for the 864 MHz field and 0.12 W kg(-1) for the 935 MHz field. <u>In comparison to the control cell samples, the growth curve of the 864 MHz irradiated cells showed a significant decrease after two-hour and three-hour exposure on the Day 3 after exposure. Likewise, cells exposed to 935 MHz</u>

microwaves for three hours showed a significant growth on Day 3 after exposure. The colony-forming ability and viability of cells exposed to 864 MHz and 935 MHz microwaves did not significantly differ from the matched controls. The applied RF/MW fields showed a similar effect on cell culture growth, colony-forming ability and viability of V79 cells.

Penafiel LM, Litovitz T, Krause D, Desta A, Mullins JM, Role of modulation on the effect of microwaves on ornithine decarboxylase activity in L929 cells. Bioelectromagnetics 18(2):132-141, 1997.

The effect of 835 MHz microwaves on the activity of ornithine decarboxylase (ODC) in L929 murine cell was investigated at an SAR of approximately 2.5 W/kg. The results depended upon the type of modulation employed. AM frequencies of 16 Hz and 60 Hz produced a transient increase in ODC activity that reached a peak at 8 h of exposure and returned to control levels after 24 h of exposure. In this case, ODC was increased by a maximum of 90% relative to control levels. A 40% increase in ODC activity was also observed after 8 h of exposure with a typical signal from a TDMA digital cellular telephone operating in the middle of its transmission frequency range (approximately 840 MHz). This signal was burst modulated at 50 Hz, with approximately 30% duty cycle. By contrast, 8 h exposure with 835 MHz microwaves amplitude modulated with speech produced no significant change in ODC activity. Further investigations, with 8 h of exposure to AM microwaves, as a function of modulation frequency, revealed that the response is frequency dependent, decreasing sharply at 6 Hz an 600 Hz. Exposure with 835 MHz microwaves, frequency modulated with a 60 Hz sinusoid, yielded no significant enhancement in ODC activity for exposure times ranging between 2 and 24 h. Similarly, exposure with a typical signal from an AMPS analog cellular telephone, which uses a form of frequency modulation, produced no significant enhancement in ODC activity. Exposure with 835 MHz continuous wave microwaves produced no effects for exposure times between 2 and 24 h, except for a small but statistically significant enhancement in ODC activity after 6 h of exposure. Comparison of these results suggests that effects are much more robust when the modulation causes low-frequency periodic changes in the amplitude of the microwave carrier.

Podkovkin VG, [The modification of the effect of microwave radiation on the biochemical processes in anaphylactic shock by using exposure to a weak and perturbed geomagnetic field]. Radiobiologiia 33(1):166-169, 1993. [Article in Russian]

Repeated exposure of guinea pigs to microwave radiation (1 mW/cm2) caused in some animals inhibition of anaphylactic response accompanied by increasing the content of histamine, epinephrine and norepinephrine in the blood. This increase was more pronounced in irradiated guinea pigs died from anaphylactic shock than in nonirradiated animals. The long-term stay in the perturbed and weak geometric field reduced the effect induced by microwave radiation.

Pu, JS, Chen, J, Yang, YH, Bai, YQ, The effects of 3000 MHz microwave irradiation on electroencephalic energy and energy metabolism in mouse brain. Electro-and Magnetobiology 16:243-247, 1997.

Mice were exposed to 3000 MHz PW 1h daily for 7 days, with long axes parallel to the magnetic field in an anechoic chamber. The average power density was 5mW/cm^2, and the estimated SAR was about 2 W/kg. There was no significant core temperature rise in the mice after exposure. After the last irradiation, mice were euthanized and the whole brain were frozen. Half of each brain were measured for SDH, and the other half for ATP. Results showed that the ATP in the brains and SDH in the hippocampus and hypothalamus in the irradiation group were significantly decreased as compared to the control. The authors suggested that the decrease in SDH caused the decrease in ATP.

Qiao S, Peng R, Yan H, Gao Y, Wang C, Wang S, Zou Y, Xu X, Zhao L, Dong J, Su Z, Feng X, Wang L, Hu X. Reduction of Phosphorylated Synapsin I (Ser-553) Leads to Spatial Memory Impairment by Attenuating GABA Release after Microwave Exposure in Wistar Rats. PLoS One. 2014 Apr 17;9(4):e95503. doi: 10.1371/journal.pone.0095503. eCollection 2014.

BACKGROUND: Abnormal release of neurotransmitters after microwave exposure can cause learning and memory deficits. This study investigated the mechanism of this effect by exploring the potential role of phosphorylated synapsin I (p-Syn I). METHODS: Wistar rats, rat hippocampal synaptosomes, and differentiated (neuronal) PC12 cells were exposed to microwave radiation for 5 min at a mean power density of 30 mW/cm2. Sham group rats, synaptosomes, and cells were otherwise identically treated and acted as controls for all of the following post-exposure analyses. Spatial learning and memory in rats was assessed using the Morris Water Maze (MWM) navigation task. The protein expression and presynaptic distribution of p-Syn I and neurotransmitter transporters were examined via western blotting and immunoelectron microscopy, respectively. Levels amino acid neurotransmitter release from rat hippocampal synaptosomes and PC12 cells were measured using high performance liquid chromatograph (HPLC) at 6 hours after exposure, with or without synapsin I silencing via shRNA transfection. RESULTS: In the rat experiments, there was a decrease in spatial memory performance after microwave exposure. The expression of p-Syn I (ser-553) was decreased at 3 days post-exposure and elevated at later time points. Vesicular GABA transporter (VGAT) was significantly elevated after exposure. The GABA release from synaptosomes was attenuated and p-Syn I (ser-553) and VGAT were both enriched in small clear synaptic vesicles, which abnormally assembled in the presynaptic terminal after exposure. In the PC12 cell experiments, the expression of p-Syn I (ser-553) and GABA release were both attenuated at 6 hours after exposure. Both microwave exposure and p-Syn I silencing reduced GABA release and maximal reduction was found for the combination of the two, indicating a synergetic effect. CONCLUSION: p-Syn I (ser-553) was found to play a key role in the impaired GABA release and cognitive dysfunction that was induced by microwave exposure.

Quock RM, Klauenberg BJ, Hurt WD, Merritt JH , Influence of microwave exposure on chlordiazepoxide effects in the mouse staircase test. Pharmacol Biochem Behav 47(4):845-849, 1994.

To ascertain whether behavioral effects of benzodiazepines are altered by exposure to microwave radiation, we compared the performance of male, Swiss CD1 mice in the staircase test 30 min after pretreatment with chlordiazepoxide (8, 16, and 32 mg/kg, IP) and immediately following a 5-min exposure to microwave radiation (4, 12, and 36 W/kg, continuous wave, 1.8 or 4.7 GHz). In this paradigm, chlordiazepoxide reduction in the number of rears (NR) and number of steps ascended (NSA) is postulated to reflect anxiolytic and sedative drug effects, respectively. In sham-exposed mice, increasing doses of chlordiazepoxide increased NSA without affecting NR, increased NSA and decreased NR, then decreased both NSA and NR. Microwave exposure generally did not alter NSA or NR in mice pretreated with lower doses of chlordiazepoxide. However, in mice pretreated with 32 mg/kg chlordiazepoxide, exposure to 36 W/kg microwave radiation significantly reversed the reductions in NSA and NR at 4.7 GHz but not at 1.8 GHz. <u>These findings indicate that exposure to microwave radiation can selectively alter effects of chlordiazepoxide in this psychopharmacological paradigm.</u>

Radicheva N, Mileva K, Georgieva B, Kristev I. Long-lasting (fatiguing) activity of isolated muscle fibres influenced by microwave electromagnetic field. Acta Physiol Pharmacol Bulg 26(1-2):37-40, 2001.

The study aims to clarify the effect of exposure to microwave electromagnetic field (MMW) on muscle fibre fatigue. Repetitive stimulation with interstimulus interval of 200 ms was applied on isolated frog muscle fibre to evoke intracellular action potentials and twitch contractions. After their recording muscle fibre preparation was moved in a Petri dish with radius of 28 mm on open air for one hour exposure to continuous MMW with frequency of 2.45 GHz and power density of 20 mW/cm2. Then it was again moved in the chamber with non irradiated Ringer's solution at controlled temperature for the repeated records. After MMW exposure the changes in amplitude and time parameters characterizing fatigue were attenuated and delayed vs. controls. The twitch amplitude curve described an drastic fall in the first 5 sec followed by an increase and next decrease. <u>MMW (2.45 GHz) have a specific, non-thermal influence on muscle fibre activity resulting in some resistance to fatigue.</u>

Raslear TG, Akyel Y, Bates F, Belt M, Lu ST, Temporal bisection in rats: the effects of high-peak-power pulsed microwave irradiation. *Bioelectromagnetics* 14(5):459-478, 1993.

The effects of high-peak-power, pulsed microwaves on a time perception and discrimination task were studied in rats. Exposures were performed with the TEMPO exposure system, which produces an 80 nanosecond pulse with peak-power levels in excess of 700 megawatts. The ability to expose animals to such fields within a controlled environment is unique. As determined by calorimetry, a maximal, whole-body-averaged, specific-absorption rate of 0.072 W/kg was produced. Thus exposures were well below a recommended SAR limit of 0.4 W/kg. Power levels of transmitted microwaves were varied over a 50 dB range to obtain ascending and descending dose-response functions for each of the behavioral measures. Measures of time perception, response bias, and total trials did not change with power level. Dose-response effects were observed for discriminability (ability to distinguish between durations), session time, and trial completions (null responses, failures to respond on a trial). Covarying sound and X-ray exposures produced by TEMPO did not reliably correlate with the observed microwave effects. The observation of repeatable dose-response effects on discriminability and null responses indicates that the microwave exposures were affecting cognitive function in the rats, particularly the decision-making process.

Ray S, Behari J, Physiological changes in rats after exposure to low levels of microwaves. *Radiat Res* 123(2):199-202, 1990.

The effects of exposure to sublethal levels of microwaves were studied. Young albino rats of both sexes were exposed for 60 days to 7.5-GHz microwaves (1.0-KHz square wave modulation, average power 0.6 mW/cm2) for 3 h daily. During and after microwave exposure several physiological parameters were measured in both control and exposed animals. It was found that the animals exposed to microwaves tended to eat and drink less and thus showed a smaller gain in body weight. Some of the hematological parameters and organ weights were also significantly different. It is proposed that a nonspecific stress response due to microwave exposure and mediated through the central nervous system is responsible for the observed physiological changes.

Rittweger J, Lambertz M, Kluge W, Kramer K, Langhorst P, Influence of modulated high-frequency electromagnetic fields on the functional organization and dynamics of the common brainstem system. Bioelectrochem Bioenerg 37(1):31-37, 1995.

The immediate influence of low-frequency modulated high-frequency electromagnetic fields (MHF) on regulatory patterns in the state of relaxed wakefulness was investigated in five healthy volunteers. The differences in magnetoencephalogram, heart frequency and ventilatory parameters before and after occipital application of MHF indicate that the effects can be explained by an influence on the common brainstem system (CBS). The CBS is part of the central nervous system which organizes and regulates the prerequisites necessary for the execution of meaningful behaviour.

Rodina A, Lass J, Riipulk J, Bachmann T, Hinrikus H. Study of effects of low level microwave field by method of face masking. Bioelectromagnetics. 26(7):571-577, 2005.

The aim of this study was to examine experimentally effects of low level, modulated microwaves on human central nervous system function utilizing the phenomenon of visual masking. Ten healthy volunteers, four males and six females, were exposed to electromagnetic field (450 MHz, 0.16 mW/cm2) with 7 Hz modulation frequency. Two photo series (visual stimuli) of unfamiliar, young male faces were presented to the subjects, one picture after another. All the photos were frontal views of unfamiliar faces, which could be recognized only by their unique combinations of features. The task was to identify the pictures from a group of six photos and to decide which order they were presented in. The phenomenon of visual masking is revealed as anamorphosis in subject's perception of two instantaneous visual stimuli presented within a short time interval. When both stimuli were to be recognized correctly and put in the right order, there was a statistically significant difference ($P < 0.05$) between the identification of the stimulus with microwave electromagnetic field and sham exposure. Recognition of both stimuli in a pair was better under the sham exposure conditions but the actual difference was only 5%. It was concluded that early stages of visual information processing are overwhelmingly robust and routine (and adaptively significant) activities, so that the low level 7 Hz modulated electromagnetic field effects exerted upon it are extremely weak.

Rojavin MA, Ziskin MC, Electromagnetic millimeter waves increase the duration of anaesthesia caused by ketamine and chloral hydrate in mice. Int J Radiat Biol 72(4):475-480, 1997.

BALB/c mice were injected i.p. with either ketamine 80 mg/kg or chloral hydrate 450 mg/kg. Anaesthetized mice were exposed to unmodulated electromagnetic millimeter waves at the frequency of 61.22 GHz with a peak specific absorption rate of 420 W/kg and corresponding incident power density of 15 mW/cm2 for 15 min or sham-exposed. In combination with either of the anaesthetics used, mm waves increased the duration of anaesthesia by approximately 50% ($p < 0.05$) in a dose (power)-dependent manner. Sham exposure to mm waves did not affect the sleeping time of mice. Pretreatment of mice with naloxone, an opioid antagonist, did not change the duration of anaesthesia caused by the corresponding chemical agent, but completely blocked or decreased the additional effect of mm waves. The data in this study indicates that exposure of mice to mm waves in vivo releases endogenous opioids or enhances the activity of opioid signalling pathway.

Romano-Spica V, Mucci N, Ursini CL, Ianni A, Bhat NK, Ets1 oncogene induction by ELF-modulated 50 MHz radiofrequency electromagnetic field. Bioelectromagnetics 21(1):8-18, 2000.

We have analyzed gene expression in hemopoietic and testicular cell types after their exposure to 50 MHz radiofrequency (RF) non-ionizing radiation modulated (80%) with a 16 Hz frequency. The exposure system generates a 0.2 microT magnetic field parallel to the ground and a 60 V/m electric field orthogonal to the earth's magnetic field. Exposure conditions were selected so as to interfere with the calcium ion flow. Under these electromagnetic field (EMF) conditions, we observed an overexpression of the ets1 mRNA in Jurkat T-lymphoblastoid and Leydig TM3 cell lines. This effect was observed only in the presence of the 16 Hz modulation, corresponding to the resonance frequency for calcium ion with a DC magnetic field of 45.7 microT. We have also identified a putative candidate gene repressed after EMF exposure. The experimental model described in this paper may contribute to the understanding of the biological mechanisms involved in EMF effects.

Rosaspina S, Salvatorelli G, Anzanel D, Bovolenta R, Effect of microwave radiation on Candida albicans. Microbios 78(314):55-59, 1994.

Microwave exposure (90 s) provides an effective, rapid sterilization for surgical scalpel blades which have been contaminated with Candida albicans. SEM analysis showed that microwave irradiation induced a morphological modification of the cells. The longer the exposure time the greater such alterations and this micro-organism in effect fractures after 9 min. No evidence was found of morphological alteration of the fungus after being submerged in boiling water for the same amount of time even though cell death was actually achieved.

Rotkovska D, Bartonickova A, Kautska J, Effects of microwaves on membranes of hematopoietic cells in their structural and functional organization. Bioelectromagnetics 14(1):79-85, 1993.

The role of cell membranes in stimulating and inhibiting the effects of microwaves was investigated in experiments carried out with a suspension of murine bone marrow cells irradiated with microwaves in vitro [f = 2.45 GHz, CW, specific absorption rate (SAR) = 12 W/kg]. Results obtained by means of a structural probe, 2.4-TNS, indicate that no structural changes occur in the region of the protein-lipid interphase under conditions of short-term irradiation with microwaves that induced temperatures in the range 36-45 degrees C (exposure time 315 and 525 s, respectively). Investigation of one functional parameter--the ability to produce hematopoietic colonies in the spleen after transplantation of the bone marrow irradiated in vitro by microwaves--indicated the possibility of affecting stimulatory and inhibitory effects of microwaves by using a blocker of cell receptors, Trimepranol. The role of microwaves as a physical factor interfering in the process of cell proliferation at the level of receptor regulation is discussed.

Saffer JD, Profenno LA, Microwave-specific heating affects gene expression. Bioelectromagnetics 13(1):75-78, 1992.

The effects of low-level microwave radiation on gene expression in Escherichia coli have been examined in a sensitive model. We confirm the previously reported existence of an increase in beta-galactosidase expression by microwave radiation--an increase not duplicated by bulk heating. However, the effect was not frequency dependent and appeared to be due to heating effects peculiar to microwaves. These results indicate that small thermal gradients may be a source of biological effects of non-ionizing radiation.

Safronova VG, Gapeev AB, Alovskaia AA, Gabdulkhakova AG, Chemeris NK, Fesenko EE [Millemetre waves inhibit the synergistic effect of calcium ionophore A23187 and phorbol ester in neutrophil respiratory burst]. Biofizika 42(6):1267-1273, 1997. [Article in Russian]

The effect of extremely high frequency electromagnetic field (mm-waves) on respiratory burst of neutrophils was studied. The peritoneal evoked neutrophils of the mice (NMRI line) were used. The production of reactive oxygen species was estimated by luminol-dependent chemiluminescence technique. Cells were irradiated by the mm-waves of 41. 95 GHz in the far field zone of the channel radiator during 20 min. Absorbed energy flux density was 150 microW/cm2. The irradiation was carried out at different concentrations of calcium ionophore A23187 and then neutrophils were stimulated by phorbol 12-myristate 13-acetate (PMA) 1 microM, activator of PKC. At irradiation of neutrophils the synergistic action of A23187 and PMA was not changed at low concentration of ionophore 10 nM-0.5 microM and was suppressed at high concentrations 0.5-10 microM. The largest inhibition of about 60% was obtained at the concentration of A23187 20 microM. The effect of mm-waves was not found under exposure in Ca(2+)-free medium for all used A23187 concentrations. <u>We suggest that the mm-wave effect on the production of reactive oxygen species by neutrophils is determined by the influx of extracellular Ca2+ and PKC.</u>

Sagioglou NE, Manta AK, Giannarakis IK, Skouroliakou AS, Margaritis LH. Apoptotic cell death during Drosophila oogenesis is differentially increased by electromagnetic radiation depending on modulation, intensity and duration of exposure. Electromagn Biol Med. 2014 Oct 21:1-14. [Epub ahead of print]

Abstract Present generations are being repeatedly exposed to different types and doses of non-ionizing radiation (NIR) from wireless technologies (FM radio, TETRA and TV stations, GSM and UMTS phones/base stations, Wi-Fi networks, DECT phones). <u>Although there is controversy on the published data regarding the non-thermal effects of NIR, studies have convincingly demonstrated bioeffects. Their results indicate that modulation, intensity, exposure duration and model system are important factors determining the biological response to irradiation.</u> Attempting to address the dependence of NIR bioeffectiveness on these factors, apoptosis in the model biological system Drosophila melanogaster was studied under different exposure protocols. A signal generator was used operating alternatively under Continuous Wave (CW) or Frequency Modulation (FM) emission modes, at three power output values (10 dB, 0, -10 dB), under four carrier frequencies (100, 395, 682, 900 MHz). Newly emerged flies were exposed either acutely (6 min or 60 min on the 6th day), or repeatedly (6 min or 60 min daily for the first 6 days of their life). <u>All exposure protocols resulted in an increase of apoptotic cell death (ACD) observed in egg chambers, even at very low electric field strengths. FM waves seem</u>

to have a stronger effect in ACD than continuous waves. Regarding intensity and temporal exposure pattern, EMF-biological tissue interaction is not linear in response. Intensity threshold for the induction of biological effects depends on frequency, modulation and temporal exposure pattern with unknown so far mechanisms. Given this complexity, translating such experimental data into possible human exposure guidelines is yet arbitrary.

Salford LG, Brun A, Sturesson K, Eberhardt JL, Persson BR Permeability of the blood-brain barrier induced by 915 MHz electromagnetic radiation, continuous wave and modulated at 8, 16, 50, and 200 Hz. Microsc Res Tech 27(6):535-542, 1994.

Biological effects of electromagnetic fields (EMF) on the blood-brain barrier (BBB) can be studied in sensitive and specific models. In a previous investigation of the permeability of the blood-brain barrier after exposure to the various EMF-components of proton magnetic resonance imaging (MRI), we found that the exposure to MRI induced leakage of Evans Blue labeled proteins normally not passing the BBB of rats [Salford et al. (1992), in: Resonance Phenomena in Biology, Oxford University Press, pp. 87-91]. In the present investigation we exposed male and female Fischer 344 rats in a transverse electromagnetic transmission line chamber to microwaves of 915 MHz as continuous wave (CW) and pulse-modulated with repetition rates of 8, 16, 50, and 200 s-1. The specific energy absorption rate (SAR) varied between 0.016 and 5 W/kg. The rats were not anesthetized during the 2-hour exposure. All animals were sacrificed by perfusion-fixation of the brains under chloral hydrate anesthesia about 1 hour after the exposure. The brains were perfused with saline for 3-4 minutes, and thereafter fixed in 4% formaldehyde for 5-6 minutes. Central coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 microns. Albumin and fibrinogen were demonstrated immunohistochemically. The results show albumin leakage in 5 of 62 of the controls and in 56 of 184 of the animals exposed to 915 MHz microwaves. Continuous wave resulted in 14 positive findings of 35, which differ significantly from the controls (P = 0.002).

Sandblom J, Theander S, The effect of microwave radiation on the stability and formation of gramicidin-A channels in lipid bilayer membranes. Bioelectromagnetics 12(1):9-20, 1991.

The effects of microwaves on the single-channel kinetics of gramicidin-A channels in lipid bilayer membranes were examined. Attempts were made to separate thermal and athermal effects by accurate measurements of temperature at the site of the membrane and by relating the measured parameters to their previously characterized temperature dependence. It was found that microwave radiation does not affect single-channel conductance or channel life time to a degree that is significantly different from that expected of a purely thermal effect. On the other hand, the rate of channel formation is decreased during exposure, which is opposite to that expected of a purely thermal effect. The mechanism of this effect is discussed in terms of the dimerization process of channel formation.

Schilling, CJ, Effects of acute exposure to ultrahigh radiofrequency radiation on three antenna engineers. Occup Environ Med 54(4):281-284, 1997.

Three men were accidentally exposed to high levels of ultrahigh frequency radiofrequency radiation (785 MHz mean frequency) while working on a television mast. They experienced an immediate sensation of intense heating of the parts of the body in the electromagnetic field followed by a variety of symptoms and signs which included pain, headache, numbness, and parasthesiae, malaise, diarrhoea, and skin erythema. The most notable problem was that of acute then chronic headache involving the part of the head which was most exposed.

Schilling CJ, Effects of exposure to very high frequency radiofrequency radiation on six antenna engineers in two separate incidents. Occup Med 60:49-56, 2000.

Six men are likely to have been accidentally exposed to high levels of very high frequency (VHF) radiofrequency radiation (100 MHz) while working on transmission masts; four men in one incident and two in another. They experienced symptoms and signs which included headache, parasthesiae, diarrhoea, malaise and lassitude. The condition of four men, two men from each incident likely to have had the highest exposure, has shown no significant improvement. The first incident occurred in 1995 and the second in 1996.

Schwartz JL, House DE, Mealing GA, Exposure of frog hearts to CW or amplitude-modulated VHF fields: selective efflux of calcium ions at 16 Hz. Bioelectromagnetics 11(4):349-358, 1990.

Isolated frog hearts were exposed for 30-min periods in a Crawford cell to a 240-MHz electromagnetic field, either continuous-wave or sinusoidally modulated at 0.5 or 16 Hz. Radiolabeled with calcium (45Ca), the hearts were observed for movement of Ca2+ at calculated SARs of 0.15, 0.24, 0.30, 0.36, 1.50, or 3.00 mW/kg. Neither CW radiation nor radiation at 0.5 Hz, which is close to the beating frequency of the frog's heart, affected movement of calcium ions. When the VHF field was modulated at 16 Hz, a field-intensity-dependent change in the efflux of calcium ions was observed. Relative to control values, ionic effluxes increased by about 18% at 0.3 mW/kg (P less than .01) and by 21% at 0.15 mW/kg (P less than .05), but movement of ions did not change significantly at other rates of energy deposition. These data indicate that the intact myocardium of the frog, akin to brain tissue of neonatal chicken, exhibits movement of calcium ions in response to a weak VHF field that is modulated at 16 Hz.

Seaman RL, Belt ML, Doyle JM, Mathur SP, Hyperactivity caused by a nitric oxide synthase inhibitor is countered by ultra-wideband pulses. Bioelectromagnetics 20(7):431-439, 1999.

Potential action of ultra-wideband (UWB) electromagnetic field pulses on effects of N(G)-nitro- L-arginine methyl ester (L-NAME), an inhibitor of nitric oxide synthase (NOS), on nociception and locomotor activity was investigated in CF-1 mice. Animals were injected IP with saline or 50 mg/kg L-NAME and exposed for 30 min to no pulses (sham exposure) or UWB pulses with electric field parameters of 102+/-1 kV/m peak amplitude, 0.90+/-0.05 ns duration, and 160+/-5 ps rise time (mean+/-S.D.) at 600/s. Animals were tested for thermal nociceptive responses on a 50 degrees C surface and for spontaneous locomotor activity for 5 min. L-NAME by itself increased mean first-response (paw lift, shake, or lick; jump) and back-paw-lick response latencies and mean locomotor activity. Exposure to UWB pulses reduced the L-NAME-induced increase in back-paw-lick latency by 22%, but this change was not statistically significant. The L-NAME-induced hyperactivity was not present after UWB exposure. Reduction and cancellation of effects of L-NAME suggest activation of opposing mechanism(s) by the UWB pulses, possibly including increase of nitric oxide production by NOS. The action, or actions, of UWB pulses appears to be more effective on locomotor activity than on thermal nociception in CF-1 mice.

Sefidbakht Y, Hosseinkhani S, Mortazavi M, Tavakkolnia I, Khellat MR, Shakiba-Herfeh M, Saviz M, Faraji-Dana R, Saboury AA, Sheibani N, Moosavi-Movahedi AA. Effects of 940 MHz EMF on Luciferase Solution: Structure, Function, and Dielectric Studies. Bioelectromagnetics. 2013 Apr 30. doi: 10.1002/bem.21792. [Epub ahead of print]

We designed a rectangular waveguide exposure system to study the effects of mobile phone frequency (940 MHz) electromagnetic fields (EMF) on luciferase structure and activity. The luciferase activity of exposed samples was significantly higher than that of unexposed samples. Dynamic light scattering of the exposed samples showed smaller hydrodynamic radii compared to unexposed samples (20 nm vs. 47 nm ± 5%). The exposed samples also showed less tendency to form aggregates, monitored by turbidity measurements at λ = 360 nm. A microwave dielectric measurement was performed to study the hydration properties of luciferase solutions with a precision network analyzer over frequency ranges from 0.2 to 20 GHz before and after exposure. The change in the dielectric properties of the exposed luciferase solution was related to the disaggregation potency of the applied field. Together, our results suggested that direct interactions with luciferase molecules and its dipole moment were responsible for the reduced aggregation and enhanced luciferase activity upon exposure to the EMF.

Semin IuA, Shvartsburg LK, Dubovik BV. [Changes in the secondary structure of DNA under the influence of external low-intensity electromagnetic field] Radiats Biol Radioecol 35(1):36-41, 1995. [Article in Russian]

The effect of weak RF on the stability of DNA secondary structure was studied in vitro. DNA was exposed in the presence of glycine and formaldehyde. Aminomethynol compounds, which form in this medium, react with DNA bases at single-strand sites, which prevents recovery from damage to the DNA secondary structure. The damage accumulates during the incubation, and its amount canbe estimated from the dynamics of thermal DNA denaturalization after RF or sha exposure. Samples were exposed in an anechoic chamber at 18°C at 10 different microwave frequencies simultaneously (4- to 8 GHz, 25 ms pulses, 0.4 to 0.7 mW/cm2 peak power, 1- to 6-Hz repetition rate, no heating). Parallel control samples were sham exposed in a shielded area in the same chamber. The experiments established that irradiation at 3 or 4 Hz and 0.6 mW/cm2 peak power clearly increased the accumulated damage to the DNA secondary structure (P< .00001). However, changing the pulse repetition rate to 1, 5, 6 Hz, as well as changing the peak power to 0.4 or 0.7 mW/cm2, eliminated the effect entirely. Thus, the effect occurred only within narrow 'windows' of the peak intensities and modulation frequencies.

Solomentsev GY, English NJ, Mooney DA.Hydrogen bond perturbation in hen egg white lysozyme by external electromagnetic fields: a nonequilibrium molecular dynamics study.J Chem Phys. 133(23):235102, 2010.

Nonequilibrium molecular dynamics simulations of a charge-neutral mutant of hen egg white lysozyme have been performed at 300 K and 1 bar in the presence of external microwave fields (2.45 to 100 GHz) of an rms electric field intensity of 0.05 V Å(-1). A systematic study was carried out of the distributions of persistence times and energies of each intraprotein hydrogen bond in between breakage and reformation, in addition to overall persistence over 20 ns simulations, vis-á-vis equilibrium, zero-field conditions. It was found that localized translational motion for formally charged residues led to greater disruption of associated hydrogen bonds, although induced rotational motion of strongly dipolar residues also led to a degree of hydrogen bond perturbation. These effects were most apparent in the solvent exposed exterior of hen egg white lysozyme, in which the intraprotein hydrogen bonds tend to be weaker.

Shcheglov VS, Alipov ED, Belyaev IY. Cell-to-cell communication in response of E. coli cells at different phases of growth to low-intensity microwaves. Biochim Biophys Acta 1572(1):101-106, 2002.

Effects of millimeter waves (MMW) at the frequency of 51.755 GHz were studied in logarithmic and stationary E. coli cells at various cell densities. The changes in the genome conformational state (GCS) were analyzed by the method of anomalous viscosity time dependence (AVTD). Before lysis, the cells were adjusted to the cell density of 4x10(7) cells/ml and all AVTD measurements were run at this cell density. Stationary cells responded to MMW by increase in AVTD, while the same MMW exposure decreased AVTD in logarithmic cells. MMW effects depended on cell density during exposure and were stronger for stationary cells. The observed dependence on cell density suggested a cell-to-cell communication between cells during exposure to microwaves. Decrease in power density (PD) resulted in more striking differences between responses at different cell densities. The data provided evidence that intercellular communication in response to MMW depended on cell status and PD of microwaves. The MMW effects were studied in more detail at low intensity of 10(-17) W/cm(2) in the range of cell densities 4x10(7) to 8x10(8) cells/ml. The obtained sigmoid-like dependence of MMW effect on cell density saturated at approximately 5x10(8) cells/ml. The dependence of MMW effect on cell density was very similar in this study and in previous studies with weak extremely low frequency (ELF) electromagnetic fields (EMF). The data suggested that cell-to-cell communication might be involved in response of cells to weak EMF of various frequency ranges.

Shckorbatov YG, Grigoryeva NN, Shakhbazov VG, Grabina VA, Bogoslavsky AM, Microwave irradiation influences on the state of human cell nuclei. Bioelectromagnetics 19(7):414-419, 1998.

Changes of electrokinetic properties of cell nuclei and the quantity of granules of heterochromatin located near the nuclear envelope in nuclei of human buccal epithelium cells were studied under the influence of electromagnetic fields in vitro. Irradiation of cells was realized by means of a semiconductor generator of millimeter radiation (wavelength 7.1 mm, frequency 42.2 GHz), the Yav-1 apparatus for extremely high frequency therapy. It was shown that irradiation of cells induced a decrease in electric charge of native human buccal epithelium cell nuclei and an increase in chromatin condensation in nuclei. The observed effects depend on irradiation dose and individual peculiarities of donors.

Shckorbatov YG, Shakhbazov VG, Navrotskaya VV, Grabina VA, Sirenko SP, Fisun AI, Gorobets NN, Kiyko VI. Application of intracellular microelectrophoresis to analysis of the influence of the low-level microwave radiation on electrokinetic properties of nuclei in human epithelial cells. Electrophoresis 23(13):2074-2079, 2002.

Intracellular microelectrophoresis was applied to investigate the electrokinetic properties of human buccal epithelium cell nuclei after exposure of cells to microwaves of wavelengths of 8 mm (f = 37.5 GHz) and 16 mm (f = 18.75 GHz) at a surface power density of 0.2 mW/cm(2). Irradiated or nonirradiated cells were suspended in a flat microelectrophoretic chamber and exposed to an electric field of 15 V/cm at a current flow of 0.1 mA. The cells, whose nuclei altered their intracellular location towards the anode of the externally applied electric field, were considered to have negatively charged nuclei. The percentage of cells with electrophoretically movable nuclei was determined as the value of electronegativity of cell nuclei (ENN). Microwaves induced changes of ENN during irradiation of 15-60 s. If cells of a donor had an elevated initial level of ENN, it decreased during irradiation. On the contrary, if cells of another donor had a low initial ENN level, irradiation induced ENN increase. No significant difference between the action of microwaves of wavelengths of 8 mm and 16 mm was found. However, microwave irradiation caused an increase in membrane permeability for the in vivo dye indigo Carmine in cells of all donors irrespectively of the initial levels they showed. This suggests that electrokinetic properties of nuclei in cells do not only depend on cell membrane permeability.

Sharma A, Sisodia R, Bhatnagar D, Saxena VK. Spatial memory and learning performance and its relationship to protein synthesis of Swiss albino mice exposed to 10 GHz microwaves. Int J Radiat Biol. 2013 Aug 19. [Epub ahead of print]

Purpose: To study the possible role of microwave (MW) exposure on spatial memory of Swiss albino mice and its relationship to protein concentration in whole brain. Materials and methods: Mice were exposed to 10 GHz (Giga Hertz) microwaves with the power density of 0.25 mW/cm^2 (milliwatt per centimeter square) with average whole body specific absorption rate (SAR) 0.1790 W/kg daily for 2 hours per day (h/day) for 30 days. After exposure mice were tested for spatial memory performance using Morris water maze test (MWT). For this purpose mice (6-8 weeks old) were divided into two groups (i) sham exposed and, (ii) microwaves exposed. After initial training for two days, MWT was performed for another 6 days. Protein was estimated 48 hours after exposure and immediately after completion of MWT. Results: Both sham exposed and microwave exposed animals showed a significant decrease in escape time with training. Microwave exposed animals had statistically significant higher mean latency to reach the target quadrant compared to sham exposed. A concurrent decrease in protein levels was estimated in whole brain of the exposed mice compared to sham exposed mice. <u>Conclusions: It can be concluded from the current study that exposure to microwave radiation caused decrements in the ability of mice to learn the special memory task, this may be due to simultaneous decrease in protein levels in the brain of mice.</u>

Sidorenko A, Tsaryuk V, Effects of microwave radiation and strychnine on cerebral biopotentials in narcotized rats. Bull Exp Biol Med 130(9):835-837, 2000.

Strychnine and microwave radiation produced changes in spectral parameters of electrocorticogram, correlation dimension, and Kolmogorov entropy, parameters calculated by the methods of nonlinear dynamics opposite to those induced by urethane. <u>The modulatory effect of microwaves on bioelectric cerebral activity in narcotized animals was similar to the effect of strychnine and probably related to enhanced excitability of brain structures and complication of bioelectric processes.</u>

Singh B, Bate LA, Responses of pulmonary intravascular macrophages to 915-MHz microwave radiation: ultrastructural and cytochemical study. Anat Rec 246(3):343-355, 1996.

BACKGROUND: Microwave (MW) radiation is being increasingly used as a source of heat supplementation during early postnatal development of pigs. Although MW radiation does not cause deleterious physiological effects, no specific information exists regarding its impact on immune cells such as macrophages. Pulmonary intravascular macrophages (PIMs) are emerging as important inflammatory cells due to their endocytic and secretory potential. An in vivo study was conducted to evaluate the effects of infrared, and low and high power MW radiation on the PIMs of pigs. METHODS: Pigs were exposed to infrared (IR), low MW (LMW; 6.1mW cm-2), and high MW (HMW; 11.4mW cm-2) radiation at 915 MHz (n = 2 for each treatment) for 24 hr. The controls (n = 2) were exposed to natural light for the same period of time. Lung tissues were processed for ultrastructural examination and acid phosphatase (AcPase) cytochemistry. In addition, rough endoplasmic reticulum (RER) as a fraction of cytosol of the PIMs was counted. RESULTS: Ultrastructural and numerical data suggested enhanced secretory activity in the PIMs of LMW-treated pigs as indicated by the increased RER:cytoplasm ratio, prominent Golgi complex profiles, and accumulation of secretory vesicles in conjunction with microtubules as compared with the control, IR, and HMW-exposed pigs. High MW treatment induced some damage to pulmonary interstitium as deduced from the presence of extracellular AcPase precipitates and disrupted collagen matrix. Intracellular globules were noticed in the PIMs of IR and LMW-treated pigs but not in the control and HMW-radiated animals. CONCLUSIONS: Elaboration of structural signs of secretory activity in the PIMs by LMW radiation in the absence of pulmonary pathological changes indicates its potential for cell activation in addition to the already established role of LMW in heat supplementation. This activation could be due to either increased core body temperature or initiation of intracellular signaling by the LMW radiation. This study also shows that the HMW radiation is capable of inducing pathology in the form of changes in the pulmonary interstitial matrix and may not be a good source of supplementary heat.

Singh S, Mani KV, Kapoor N. Effect of occupational EMF exposure from radar at two different frequency bands on plasma melatonin and serotonin levels. Int J Radiat Biol. 2015 Jan 7:1-39. [Epub ahead of print].

Objective: The purpose of the present study was to delineate the effect of chronic electromagnetic field (EMF) exposure from radar on plasma melatonin and serotonin levels in occupationally exposed military personnel. Subjects and Methods: 166 male military personnel participated in the study out of which only 155 joined for blood draw. They were divided into three sets viz control group (n=68), exposure group I (n=40) exposed to 8-12GHz and exposure group II (n=58) working with radar at 12.5-18GHz frequency. All the three groups were further split into two groups according to their years of service (up to 10 years and > 10 years) in order to investigate the effect of years of exposure from radar. Melatonin and serotonin levels were estimated by enzyme immunoassay in fasting blood samples collected during 0600-0700h. EMF measurements were recorded at different locations using Satimo EME Guard 'Personal Exposure Meter' and Narda 'Broad Band Field Meter'. Results: The group I exposed population registered a minor though not significant decrease in plasma melatonin concentration while the other group II exposed population registered statistically significant decline in melatonin concentration when compared with controls. Highly significant increase in plasma serotonin levels was found in exposure group II when compared to control whereas marginal non-significant rise was also registered in exposure group I in comparison to control. Exposure in terms of length of service up to 10 years did not produce any significant effect in the indoleamine levels in both the exposure groups when they were compared with their respective control groups. Whereas, length of service greater than 10 years was observed to decrease and increase respectively the melatonin and serotonin concentration significantly in exposure group II but not in exposure group I. However, correlation test did not yield any significant association between years of service and melatonin or serotonin levels respectively in both the exposure sets I and II. No significant association was observed between melatonin and serotonin levels as well. Conclusion: The study shows the EMF ability to influence plasma melatonin and serotonin concentration in radar workers, significantly in 12.5-18GHz range with service period greater than 10 years.

Szmigielski, S, Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. Sci Total Environ 180(1):9-17, 1996.

Cancer morbidity was registered in the whole population of military career personnel in Poland during a period of 15 years (1971-1985). Subjects exposed occupationally to radiofrequencies (RF) and microwaves (MW) were selected from the population on the basis of their service records and documented exposures at service posts. The population size varied slightly from year to year with a mean count of about 128,000 persons each year; each year about 3700 of them (2.98%) were considered as occupationally exposed to RF/MW. All subjects (exposed and non-exposed to RF/MW) were divided into age groups (20-29, 30-39, 40-49 and 50-59). All newly registered cases of cancer were divided into 12 types based on localisation of the malignancy; for neoplasms of the haemopoietic system and lymphatic organs an additional analysis based on diagnosis was performed. Morbidity rates (per 100,000 subjects annually) were calculated for all of the above localisations and types of malignancies both for the whole population and for the age groups. The mean value of 15 annual rates during 1971-1985 represented the respective morbidity rate for the whole period. Morbidity rates in the non-exposed groups of personnel were used as 'expected' (E) rates for the exposed subjects, while the real morbidity rates counted in the RF/MW-exposed personnel served as 'observed' (O) rates. This allowed the calculation of the observed/expected ratio (OER) representing the odds ratio for the exposed groups. The cancer morbidity rate for RF/MW-exposed personnel for all age groups (20-59 years) reached 119.1 per 100,000 annually (57.6 in non-exposed) with an OER of 2.07, significant at $P < 0.05$. The difference between observed and expected values results from higher morbidity rates due to neoplasms of the alimentary tract (OER = 3.19-3.24), brain tumours (OER = 1.91) and malignancies of the haemopoietic system and lymphatic organs (OER = 6.31). Among malignancies of the haemopoietic/lymphatic systems, the largest differences in morbidity rates between exposed and non-exposed personnel were found for chronic myelocytic leukaemia (OER = 13.9), acute myeloblastic leukaemia (OER = 8.62) and non-Hodgkin lymphomas (OER = 5.82).

Szmigielski, S, Bortkiewicz, A, Gadzicka, E, Zmyslony, M, Kubacki, R, Alteration of diurnal rhythms of blood pressure and heart rate to workers exposed to radiofrequency electromagnetic fields. Blood Press Monit 3(6):323-330, 1998.

BACKGROUND: In previous studies we found measurable effects on variability of heart rate and on blood-pressure parameters of workers exposed to radiofrequency electromagnetic fields (EMF)compared with a control population, but none of the effects could be assigned clinical significance. In general, the obtained results strongly suggested that dysregulation of the autonomic control of the circulatory system was occurring. Therefore, it seemed logical that analysis of diurnal rhythms of blood pressure and heart rate, on the basis of data from 24 h recordings, might further support the above hypothesis. OBJECTIVE: The aim of this study was to determine the course of diurnal rhythms of blood pressure and heart rate in a group of workers exposed to various intensities of radiofrequency electromagnetic fields. METHODS: In the study we used 61 healthy workers (aged 30-50 years) who had been exposed to radiofrequency EMF of 0.738-1.503 Mhz and 42 healthy workers at radio-line stations (aged 28-49 years), who had not been exposed to EMF occupationally. The work patterns of these two groups were identical (12 h day working shift, 24 h interval, 12 h night shift and then 48 h rest). During the second day of the rest period 24 h ambulatory blood pressure (ABP) was recorded. For analysis of diurnal rhythms the group of exposed workers was divided into two subgroups: group A of 38 subjects exposed to low intensities of radiofrequency EMF (20-180 V/m) and group B of 23 subjects exposed to high intensities of radiofrequency EMF (200-550 V/m). Parameters of diurnal rhythms of blood pressure and heart rate (acrophase, amplitude and mean) were calculated by performing a least-square fit of a 24 h cosinor (single cosinor analysis) at $P < 0.05$. RESULTS: Healthy men aged 28-49 years, working on a pattern of 12-24-12-48 h, exhibited typical, well-preserved diurnal rhythms of blood pressure and heart rate with two maxima (at about 1400 and 1700-1800 h) and one minimum (at about 0200-0400 h). For workers exposed to radiofrequency EMF we noted a significant lowering of the amplitudes of rhythms of blood pressure and heart rate ($P < 0.01$) and a shift of the acrophase to an earlier time (1100-1200 h; $P < 0.05$). <u>These changes were more pronounced among workers exposed to high intensities of radiofrequency EMF. CONCLUSIONS: Occupational exposure to radiofrequency EMF can result in changes of the diurnal rhythms of blood pressure and heart rate with lowering of their amplitudes and a shift of the acrophase.</u> The clinical relevance of the present finding needs to be investigated in further studies.

Tafforeau M, Verdus MC, Norris V, White GJ, Cole M, Demarty M, Thellier M, Ripoll C.Plant sensitivity to low intensity 105 GHz electromagnetic radiation. Bioelectromagnetics. 25(6):403-407, 2004.

Exposing seedlings of the flax, Linum usitatissimum L., to a variety of weak environmental stresses followed by a 2 day calcium deprivation, triggers the common response of production of epidermal meristems (actively dividing groups of cells) in the hypocotyl, which is the part of the stem between the root and the cotyledons (the pre-existing leaves in the embryo). This production reaches a plateau of 10-20 meristems after a month in the case of mechanical stimulation and cold shock. <u>Recently, we have shown that radiation from a global system for mobile communication (GSM) telephone also triggers production of meristems with a plateau of around six meristems. Here, we show that a single 2 h exposure to radiation emitted at 105 GHz at non-thermal levels by a Gunn oscillator induces meristem production with kinetics similar to that induced by weak environmental stimuli and radiation from GSM telephone.</u>

Taskinen H, Kyyronen P, Hemminki K, Effects of ultrasound, shortwaves,

and physical exertion on pregnancy outcome in physiotherapists. J Epidemiol Community Health 44(3):196-201, 1990.

STUDY OBJECTIVE--The aim of the study was to investigate whether occupational exposure among physiotherapists is associated with spontaneous abortion or congenital malformation in the offspring. DESIGN--The study was a retrospective nested case-control study, where the pregnancy outcome data were based on the medical registers. SETTING--All registered physiotherapists in Finland who had become pregnant during the study period were included in the study. SUBJECTS--Cases were defined as women who had been treated for spontaneous abortion during 1973-1983 or had delivered a malformed child during 1973-1982. One pregnancy per woman was randomly selected for the study. Three age matched (+/- 18 months) controls were selected for each abortion case and five for each malformation case. The final study population was 204 cases and 483 controls in the spontaneous abortion study, and 46 cases and 187 controls in the congenital malformation study. MEASUREMENTS AND MAIN RESULTS--Exposure information was collected by mailed questionnaires from 1329 women. The response rate was 92% in the spontaneous abortion study, and 89% in the congenital malformation study. Heavy lifting (including patient transfers) was associated significantly with spontaneous abortion. Exposure to ultrasound and shortwaves showed about threefold odds ratios for spontaneous abortions occurring after the 10th week of gestation but in analysis where potential confounding variables were controlled, neither reached statistical significance. Deep heat therapies together, and shortwaves alone, were associated significantly with congenital malformations, but the increase was found in the lower exposure category only. From the potential confounding variables, previous abortion (spontaneous or induced) was associated significantly with spontaneous abortion, and febrile disease in early pregnancy was associated with congenital malformation. CONCLUSION--Physical exertion during early pregnancy seems to be a risk factor for spontaneous abortion. <u>The findings raise suspicion of the potential harmful effect of shortwaves and ultrasound on the pregnancy,</u> but no firm conclusion can be drawn on the bases of these results alone.

Tattersall JE, Scott IR, Wood SJ, Nettell JJ, Bevir MK, Wang Z, Somasiri NP, Chen X. Effects of low intensity radiofrequency electromagnetic fields on electrical activity in rat hippocampal slices. Brain Res 904(1):43-53, 2001.

Slices of rat hippocampus were exposed to 700 MHz continuous wave radiofrequency (RF) fields (25.2-71.0 V m(-1), 5-15 min exposure) in a stripline waveguide. At low field intensities, the predominant effect on the electrically evoked field potential in CA1 was a potentiation of the amplitude of the population spike by up to 20%, but higher intensity fields could produce either increases or decreases of up to 120 and 80%, respectively, in the amplitude of the population spike. To eliminate the possibility of RF-induced artefacts due to the metal stimulating electrode, the effect of RF exposure on spontaneous epileptiform activity induced in CA3 by 4-aminopyridine (50-100 &mgr;M) was investigated. Exposure to RF fields (50.0 V m(-1)) reduced or abolished epileptiform bursting in 36% of slices tested.

The maximum field intensity used in these experiments, 71.0 V m(-1), was calculated to produce a specific absorption rate (SAR) of between 0.0016 and 0.0044 W kg(-1) in the slices. Measurements with a Luxtron fibreoptic probe confirmed that there was no detectable temperature change (+/-0.1 degrees C) during a 15 min exposure to this field intensity. Furthermore, imposed temperature changes of up to 1 degrees C failed to mimic the effects of RF exposure. These results suggest that low-intensity RF fields can modulate the excitability of hippocampal tissue in vitro in the absence of gross thermal effects. The changes in excitability may be consistent with reported behavioural effects of RF fields.

Thuroczy G, Kubinyi G, Bodo M, Bakos J, Szabo LD, Simultaneous response of brain electrical activity (EEG) and cerebral circulation (REG) to microwave exposure in rats. Rev Environ Health 10(2):135-148, 1994.

The correlations between physiological modalities in microwave field-activated systemic or localized regulatory mechanisms with changes in the central nervous system (CNS) seem not to be identical. These problems are important because of the increased number of radiating appliances, e.g. portable radios and mobile telephones. In two series of experiments on anaesthetized rats (N = 40) (i) before and after 10 min, whole body exposures to 2.45 GHz CW microwaves, and (ii) during 30 min exposures to 4 GHz amplitude modulated (AM, 16 Hz) microwaves, the effects on the CNS were observed simultaneously with those on the cardiovascular system by quantitative polygraphic measurement. In acute experiments on rats, electroencephalograms (EEG), rheoencephalograms (REG) as an index of cerebral blood flow (CBF), brain tissue DC impedance and temperature and ECG were recorded simultaneously. The total power of EEG spectra increased after whole body 30 mW/cm2 2.45 GHz CW exposure for 10 min. No changes occurred at 10 mW/cm2. The CBF increased after 10 mW/cm2 exposure. The power of EEG delta (0.5-4 Hz) waves was increased by thermal level of brain localized 4 GHz CW exposure at 42 mW/g specific absorption rate (SAR) simultaneously with the REG amplitude as an index of cerebral blood flow. Amplitude modulation at 16 Hz and 8.4 mW/g SAR was associated with increased power of EEG beta (14.5-30 Hz) waves but changes in the CBF were not observed. CW radiation at 8.4 mW/g increased the cerebral blood flow, but did not change EEG spectra.

Tynes T, Hannevik M, Andersen A, Vistnes AI, Haldorsen T, Incidence of breast cancer in Norwegian female radio and telegraph operators. Cancer Causes Control 7(2):197-204, 1996.

Exposure to electromagnetic fields may cause breast cancer in women if it increases susceptibility to sex-hormone-related cancer by diminishing the pineal gland's production of melatonin. We have studied breast cancer incidence in female radio and telegraph operators with potential exposure to light at night, radio frequency (405 kHz-25 MHz), and, to some extent, extremely low frequency fields (50 Hz). We linked the Norwegian Telecom cohort of female radio and telegraph operators working at sea to the Cancer Registry of Norway to study incident cases of breast cancer. The cohort consisted of 2,619 women who were certified to work as radio and telegraph operators between 1920 and 1980. Cancer incidence was analyzed on the basis of the standardized incidence ratio (SIR), with the Norwegian female population as the comparison group. The incidence of all cancers was close to unity (SIR = 1.2). An excess risk was seen for breast cancer (SIR = 1.5). Analysis of a nested case-control study within the cohort showed an association between breast cancer in women aged 50+ years and shift work. In a model with adjustment for age, calendar year, and year of first birth, the rate ratio for breast cancer associated with being a radio and telegraph operator--in comparison with all Norwegian women born 1935 or later--analyzed with Poisson regression, was 1.5 after adjustment for fertility factors. These results support a possible association between work as a radio and telegraph operator and breast cancer. Future epidemiologic studies on breast cancer in women aged 50 and over, should address possible disturbances of chronobiological parameters by environmental factors.

Vácha M, Puzová T, Kvícalová M. Radio frequency magnetic fields disrupt magnetoreception in American cockroach. J Exp Biol. 212(Pt 21):3473-3477, 2009.

The sense that allows birds to orient themselves by the Earth's magnetic field can be disabled by an oscillating magnetic field whose intensity is just a fraction of the geomagnetic field intensity and whose oscillations fall into the medium or high frequency radio wave bands. This remarkable phenomenon points very clearly at one of two existing alternative magnetoreception mechanisms in terrestrial animals, i.e. the mechanism based on the radical pair reactions of specific photosensitive molecules. As the first such study in invertebrates, our work offers evidence that geomagnetic field reception in American cockroach is sensitive to a weak radio frequency field. Furthermore, we show that the 'deafening' effect at Larmor frequency 1.2 MHz is stronger than at different frequencies. The parameter studied was the rise in locomotor activity of cockroaches induced by periodic changes in the geomagnetic North positions by 60 deg. The onset of the disruptive effect of a 1.2 MHz field was found between 12 nT and 18 nT whereas the threshold of a doubled frequency field 2.4 MHz fell between 18 nT and 44 nT. A 7 MHz field showed no impact even in maximal 44 nT magnetic flux density. The results indicate resonance effects rather than non-specific bias of procedure itself and suggest that insects may be equipped with the same magnetoreception system as the birds.

Vangelova K, Israel M, Mihaylov S. The effect of low level radiofrequency electromagnetic radiation on the excretion rates of stress hormones in operators during 24-hour shifts. Cent Eur J Public Health 10(1-2):24-28, 2002.

The aim of the study was to investigate the effect of long term exposure to low level radiofrequency (RF) electromagnetic (EM) radiation on the excretion rates of stress hormones in satellite station operators during 24-hour shifts. Twelve male operators at a satellite station for TV communications and space research were studied during 24-hour shifts. Dosimetric evaluation of the exposure was carried out and showed low level exposure with specific absorption of 0.1127 J.kg-1. A control group of 12 unexposed male operators with similar job task and the same shift system were studied, too. The 11-oxycorticosteroids (11-OCS), adrenaline and noradrenaline were followed by spectrofluorimetric methods on 3-hour intervals during the 24-hour shifts. The data were analyzed by tests for interindividual analysis, Cosinor analysis and analysis of variance (ANOVA). Significant increase in the 24-hour excretion of 11-OCS and disorders in its circadian rhythm, manifested by increase in the mesor, decrease in the amplitude and shift in the acrophase were found in the exposed operators. The changes in the excretion rates of the catecholamines were significant and showed greater variability of both variables. <u>The long term effect of the exposure to low-level RF EM radiation evoked pronounced stress reaction with changes in the circadian rhythm of 11-OCS and increased variability of catecholamines secretion.</u> The possible health hazards associated with observed alteration in the stress system need to be clarified by identification of their significance and prognostic relevance.

Vangelova KK, Israel MS. Variations of melatonin and stress hormones under extended shifts and radiofrequency electromagnetic radiation. Rev Environ Health. 20(2):151-161, 2005.

We studied the time-of-day variations in urinary levels of 6-sulphatoxy-melatonin and three stress hormones in operators working fast-rotating extended shifts under radiofrequency electromagnetic radiation (EMR). The excretion rate of the hormones was monitored by radioimmunoassay and spectrofluorimetry at 4-hour intervals in a group of 36 male operators comprising 12 broadcasting station operators, 12 TV station operators, and a control group of 12 satellite station operators. Measuring the time-weighted average (TWA) of EMR exposure revealed a high-level of exposure in broadcasting station operators (TWAmean= 3.10 microW/cm2, TWAmax = 137.00 microW/cm2), a low-level in TV station operators (TWAmean = 1.89 microW/cm2, TWAmax = 5.24 microW/cm2), and a very low level in satellite station operators. The differences among the groups remained the same after confounding factors were taken into account. Radiofrequency EMR had no effect on the typical diurnal pattern of 6-sulphatoxymelatonin. High-level radiofrequency EMR exposure significantly increased the excretion rates of cortisol ($p < 0.001$), adrenaline ($p = 0.028$), and noradrenaline ($p < 0.000$), whereas changes under low-level exposure did not reach significance. The 24-hour excretion of cortisol and noradrenaline correlated with TWAmean and TWAmax. <u>In conclusion, the excretion of 6-sulphatoxymelatonin retained a typical diurnal pattern under fast-rotating extended shifts and radiofrequency EMR, but showed an exposure-effect relation with stress hormones.</u>

Vangelova K, Deyanov C, Israel M.Cardiovascular risk in operators under radiofrequency electromagnetic radiation.Int J Hyg Environ Health. 209(2):133-138, 2006.

The aim of the study was to assess the long-term effects of radiofrequency electromagnetic radiation (EMR) on the cardiovascular system. Two groups of exposed operators (49 broadcasting (BC) station and 61 TV station operators) and a control group of 110 radiorelay station operators, matched by sex and age, with similar job characteristics except for the radiofrequency EMR were studied. The EMR exposure was assessed and the time-weighted average (TWA) was calculated. The cardiovascular risk factors arterial pressure, lipid profile, body mass index, waist/hip ratio, smoking, and family history of cardiovascular disease were followed. The systolic and diastolic blood pressure (SBP and DBP), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) were significantly higher in the two exposed groups. It was found that the radiofrequency EMR exposure was associated with greater chance of becoming hypertensive and dyslipidemic. The stepwise multiple regression equations showed that the SBP and TWA predicted the high TC and high LDL-C, while the TC, age and abdominal obesity were predictors for high SBP and DBP. <u>In conclusion, our data show that the radiofrequency EMR contributes to adverse effects on the cardiovascular system.</u>

Veyret B, Bouthet C, Deschaux P, de Seze R, Geffard M, Joussot-Dubien J, le Diraison M, Moreau JM, Caristan A, Antibody responses of mice exposed to low-power microwaves under combined, pulse-and-amplitude modulation. Bioelectromagnetics 12(1):47-56, 1991.

Irradiation by pulsed microwaves (9.4 GHz, 1 microsecond pulses at 1,000/s), both with and without concurrent amplitude modulation (AM) by a sinusoid at discrete frequencies between 14 and 41 MHz, was assessed for effects on the immune system of Balb/C mice. The mice were immunized either by sheep red blood cells (SRBC) or by glutaric-anhydride conjugated bovine serum albumin (GA-BSA), then exposed to the microwaves at a low rms power density (30 microW/cm2; whole-body-averaged SAR approximately 0.015 W/kg). Sham exposure or microwave irradiation took place during each of five contiguous days, 10 h/day. The antibody response was evaluated by the plaque-forming cell assay (SRBC experiment) or by the titration of IgM and IgG antibodies (GA-BSA experiment). <u>In the absence of AM, the pulsed field did not greatly alter immune responsiveness. In contrast, exposure to the field under the combined-modulation condition resulted in significant, AM-frequency-dependent augmentation or weakening of immune responses.</u>

Von Klitzing, L, Low-frequency pulsed electromagnetic fields influence EEG of man. Phys. Medica 11:77-80, 1995.

New techniques using low-frequency puled electromagnetic fields (e.g., digital telecommunication) have raised the question for interference with the biological system of man. EEG data of man sampled under the influence of these electromagnetic fields are altered extremely in the range of alpha-activity as well as during after exposure for some hours. The biological effect is induced by field intensities lower than the given international limiting values.

Vorobyov VV, Galchenko AA, Kukushkin NI, Akoev IG, Effects of weak microwave fields amplitude modulated at ELF on EEG of symmetric brain areas in rats. Bioelectromagnetics 18(4):293-298, 1997.

Averaged electroencephalogram (EEG) frequency spectra were studied in eight unanesthetized and unmyorelaxed adult male rats with chronically implanted carbon electrodes in symmetrical somesthetic areas when a weak (0.1-0.2 mW/cm2)
microwave (MW, 945 MHz) field, amplitude-modulated at extremely low frequency (ELF) (4 Hz), was applied. Intermittent (1 min "On," 1 min "Off") field exposure (10-min duration) was used. Hemispheric asymmetry in frequency spectra (averaged data for 10 or 1 min) of an ongoing EEG was characterized by a power decrease in the 1.5-3 Hz range on the left hemisphere and by a power decrease in the 10-14 and 20-30 Hz ranges on the right hemisphere. No differences between control and exposure experiments were shown under these routines of data averaging. Significant elevations of EEG asymmetry in 10-14 Hz range were observed during the first 20 s after four from five onsets of the MW field, when averaged spectra were obtained for every 10 s. Under neither control nor pre- and postexposure conditions was this effect observed. These results are discussed with respect to interaction of MW fields with the EEG generators.

Vorobyov V, Janać B, Pesić V, Prolić Z. Repeated exposure to low-level extremely low frequency-modulated microwaves affects cortex-hypothalamus interplay in freely moving rats: EEG study. Int J Radiat Biol. 86(5):376-383, 2010.

PURPOSE: To compare the effects of repeated exposure to extremely low frequency-modulated microwaves (ELF-MW) on cortical and hypothalamic electroencephalograms (EEG). MATERIALS AND METHODS: In 10 freely moving rats with carbon electrodes implanted into the cortex and dorsomedial hypothalamus, averaged frequency spectra (0.5-30 Hz) of the EEG were studied for five consecutive days either under sham exposures (five rats) or under mixed sham/MW-exposures (five rats). The rats were exposed to ELF-MW (915 MHz, 20-ms pulse duration, approximately 0.3 mW/cm(2), 4 Hz) intermittently (1-min 'On', 1-min 'Off') for 10 min (specific absorption rate, SAR, approximately 0.7 mW/g on average) several times per day, with 10-min pre- and post-exposure periods. RESULTS: In baseline EEG, the activities of 3.2-6.0 Hz and 17.8-30.5 Hz dominated in the cortex and of 6.0-17.8 Hz in the hypothalamus. This cortical-hypothalamic imbalance was relatively stable at sham-exposures and insensitive to ELF-MW in all frequency ranges but one. ELF-MW increased the beta(2) (17.8-30.5 Hz) level in the hypothalamus to a greater extent than in the cortex, causing significant diminishing of the initial EEG bias between them. Moreover, a cumulative phenomenon under repeated exposures to ELF-MW was revealed. CONCLUSIONS: These results are in line with evidence that repeated low-level exposure to ELF-MW affects brain functioning and provide an additional approach when analysing underlying mechanisms.

Walters TJ, Blick DW, Johnson LR, Adair ER, Foster KR, Heating and

pain sensation produced in human skin by millimeter waves: comparison to a simple thermal model. Health Phys 78(3):259-267, 2000.

Cutaneous thresholds for thermal pain were measured in 10 human subjects during 3-s exposures at 94 GHz continuous wave microwave energy at intensities up to approximately 1.8 W cm(-2). During each exposure, the temperature increase at the skin's surface was measured by infrared thermography. The mean (+/- s.e.m.) baseline temperature of the skin was 34.0+/-0.2 degrees C. The threshold for pricking pain was 43.9+/-0.7 degrees C, which corresponded to an increase in surface temperature of approximately 9.9 degrees C (from 34.0 degrees C to 43.9 degrees C). The measured increases in surface temperature were in good agreement with a simple thermal model that accounted for heat conduction and for the penetration depth of the microwave energy into tissue. <u>Taken together, these results support the use of the model for predicting thresholds of thermal pain at other millimeter wave (length) frequencies.</u>

Walters TJ, Ryan KL, Belcher JC, Doyle JM, Tehrany MR, Mason PA, Regional brain heating during microwave exposure (2.06 GHz), warm-water immersion, environmental heating and exercise. Bioelectromagnetics 19(6):341-353,1998.

Nonuniform heating may result from microwave (MW) irradiation of tissues and is therefore important to investigate in terms of health and safety issues. Hypothalamic (Thyp), cortical (Tctx), tympanic (Tty), and rectal (Tre) temperatures were measured in rats exposed in the far field, k-polarization (i.e., head pointed toward the transmitter horn and E-field in vertical direction) to two power densities of 2.06 GHz irradiation. The high-power density (HPM) was 1700 mW/cm2 [specific absorption rate (SAR): hypothalamus 1224 W/kg; cortex 493 W/kg]; the low-power density (LPM) was 170 mW/cm2 (SAR:
hypothalamus 122.4 W/kg; cortex 49.3 W/kg). The increase (rate-of-rise, in degrees C/s) in Thyp was significantly greater than those in Tctx or Tre when rats were exposed to HPM. LPM produced more homogeneous heating. Quantitatively similar results were observed whether rats were implanted with probes in two brain sites or a single probe in one or the other of the two sites. The

qualitative difference between regional brain heating was maintained during unrestrained exposure to HPM in the h-polarization (i.e., body parallel to magnetic field). To compare the temperature changes during MW irradiation with those produced by other modalities of heating, rats were immersed in warm water (44 degrees C, WWI); exposed to a warm ambient environment (50 degrees C, WSED); or exercised on a treadmill (17 m/min 8% grade) in a warm ambient environment (35 degrees C, WEX). WWI produced uniform heating in the regions measured. <u>Similar rates-of-rise occurred among regions following WSED or WEX, thus maintaining the pre-existing gradient between Thyp and Tctx These data</u>

indicate that HPM produced a 2-2.5-fold difference in the rate-of-heating within brain regions that were separated by only a few millimeters. In contrast, more homogeneous heating was recorded during LPM or nonmicrowave modalities of heating.

Walters TJ, Ryan KL, Belcher JC, Doyle JM, Tehrany MR, Mason PA, Regional brain heating during microwave exposure (2.06 GHz), warm-water immersion, environmental heating and exercise. Bioelectromagnetics 19(6):341-353,1998.

Nonuniform heating may result from microwave (MW) irradiation of tissues and is therefore important to investigate in terms of health and safety issues. Hypothalamic (Thyp), cortical (Tctx), tympanic (Tty), and rectal (Tre) temperatures were measured in rats exposed in the far field, k-polarization (i.e., head pointed toward the transmitter horn and E-field in vertical direction) to two power densities of 2.06 GHz irradiation. The high-power density (HPM) was 1700 mW/cm2 [specific absorption rate (SAR): hypothalamus 1224 W/kg; cortex 493 W/kg]; the low-power density (LPM) was 170 mW/cm2 (SAR:
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Wang LF, Li X, Gao YB, Wang SM, Zhao L, Dong J, Yao BW, Xu XP, Chang GM, Zhou HM, Hu XJ, Peng RY. Activation of VEGF/Flk-1-ERK Pathway Induced Blood-Brain Barrier Injury After Microwave Exposure. Mol Neurobiol. 2014 Sep 9. [Epub ahead of print]

Microwaves have been suggested to induce neuronal injury and increase permeability of the blood-brain barrier (BBB), but the mechanism remains unknown. The role of the vascular endothelial growth factor (VEGF)/Flk-1-Raf/MAPK kinase (MEK)/extracellular-regulated protein kinase (ERK) pathway in structural and functional injury of the blood-brain barrier (BBB) following microwave exposure was examined. An in vitro BBB model composed of the ECV304 cell line and primary rat cerebral astrocytes was exposed to microwave radiation (50 mW/cm2, 5 min). The structure was observed by scanning electron microscopy (SEM) and the permeability was assessed by measuring transendothelial electrical resistance (TEER) and horseradish peroxidase (HRP) transmission. Activity and expression of VEGF/Flk-1-ERK pathway components and occludin also were examined. Our results showed that microwave radiation caused intercellular tight junctions to broaden and fracture with decreased TEER values and increased HRP permeability. After microwave exposure, activation of the VEGF/Flk-1-ERK pathway and Tyr phosphorylation of occludin were observed, along with down-regulated expression and interaction of occludin with zonula occludens-1 (ZO-1). After Flk-1 (SU5416) and MEK1/2 (U0126) inhibitors were used, the structure and function of the BBB were recovered. The increase in expression of ERK signal transduction molecules was muted, while the expression and the activity of occludin were accelerated, as well as the interactions of occludin with p-ERK and ZO-1 following microwave radiation. Thus, microwave radiation may induce BBB damage by activating the VEGF/Flk-1-ERK pathway, enhancing Tyr phosphorylation of occludin, while partially inhibiting expression and interaction of occludin with ZO-1.

Wang XW, Ding GR, Shi CH, Zeng LH, Liu JY, Li J, Zhao T, Chen YB, Guo GZ. Mechanisms involved in the blood-testis barrier increased permeability induced by EMP. Toxicology. 276(1):58-63, 2010.

The blood-testis barrier (BTB) plays an important role in male reproductive system. Lots of environmental stimulations can increase the permeability of BTB and then result in antisperm antibody (AsAb) generation, which is a key step in male immune infertility. Here we reported the results of male mice exposed to electromagneticpulse (EMP) by measuring the expression of tight-junction-associated proteins (ZO-1 and Occludin), vimentin microfilaments, and transforming growth factor-beta (TGF-beta3) as well as AsAb level in serum. Male BALB/c mice were sham exposed or exposed to EMP at two different intensities (200kV/m and 400kV/m) for 200 pulses. The testes were collected at different time points after EMP exposure. Immunofluorescence histocytochemistry, western blotting, laser confocal microscopy and RT-PCR were used in this study. Compared with sham group, the expression of ZO-1 and TGF-beta3 significantly decreased accompanied with unevenly stained vimentin microfilaments and increased serum AsAb levels in EMP-exposed mice. These results suggest a potential BTB injury and immune infertility in male mice exposed to a certain intensity of EMP.

Weyandt, TB, Schrader, SM, Turner, TW, Simon, SD, Semen analysis of military personnel associated with military duty assignments. Reprod Toxicol 10(6):521-528, 1996.

A collaborative study between the U.S. Army Biomedical Research and DevelopmentLaboratory (USABRDL) and the National Institute for Occupational Safety and Health (NIOSH) was designed to assess fecundity of male artillery soldiers with potential exposures to airborne lead aerosols. Potential exposure assessment was based upon information provided in an interactive questionnaire. It became apparent from extensive questionnaire data that many soldiers in the initial control population had potentially experienced microwave exposure as radar equipment operators. As a result, a third group of soldiers without potential for lead or microwave exposures, but with similar environmental conditions, was selected as a comparison population. Blood hormone levels and semen analyses were conducted on artillerymen (n = 30), radar equipment operators (n = 20), and the comparison group (n = 31). Analysis of the questionnaire information revealed that concern about fertility problems motivated participation of some soldiers with potential artillery or microwave exposures. Although small study population size and the confounding variable of perceived infertility limit the reliability of the study, several statistically significant findings wereidentified. Artillerymen who perceived a possible fertility concern demonstrated lower sperm counts/ejaculate (P = 0.067) and lower sperm/mL (P = 0.014) than the comparison group. The group of men with potential microwave exposures demonstrated lower sperm counts/mL (P = 0.009) and sperm/ejaculate (P = 0.027) than the comparison group. Variables used to assess endocrine, accessory sex gland, and sperm cell function were not different than the comparison group. Additional studies, incorporating larger numbers of individuals, should be performed in order to more optimally characterize potential lead and microwave exposure effects on male fecundity.

Wilen J, Hornsten R, Sandstrom M, Bjerle P, Wiklund U, Stensson O, Lyskov E, Mild KH. Electromagnetic field exposure and health among RF plastic sealer operators. Bioelectromagnetics. 25(1): 5-15, 2004.

Operators of RF plastic sealers (RF operators) are an occupational category highly exposed to radiofrequency electromagnetic fields. The aim of the present study was to make an appropriate exposure assessment of RF welding and examine the health status of the operators. In total, 35 RF operators and 37 controls were included. The leakage fields (electric and magnetic field strength) were measured, as well as induced and contact current. Information about welding time and productivity was used to calculate time integrated exposure. A neurophysiological examination and 24 h ECG were also carried out. The participants also had to answer a questionnaire about subjective symptoms. The measurements showed that RF operators were exposed to rather intense electric and magnetic fields. The mean values of the calculated 6 min, spatially averaged E and H field strengths, in line with ICNIRP reference levels, are 107 V/m and 0.24 A/m, respectively. The maximum measured field strengths were 2 kV/m and 1.5 A/m, respectively. The induced current in ankles and wrists varied, depending on the work situation, with a mean value of 101 mA and a maximum measured value of 1 A. In total, 11 out of 46 measured RF plastic sealers exceeded the ICNIRP reference levels. RF operators, especially the ready made clothing workers had a slightly disturbed two-point discrimination ability compared to a control group. A nonsignificant difference between RF operators and controls was found in the prevalence of subjective symptoms, but the time integrated exposure parameters seem to be of importance to the prevalence of some subjective symptoms: fatigue, headaches, and warmth sensations in the hands. Further, RF operators had a significantly lower heart rate (24 h registration) and more episodes of bradycardia compared to controls.

Wilén J, Wiklund U, Hörnsten R, Sandström M. Changes in heart rate variability among RF plastic sealer operators. Bioelectromagnetics. 28(1):76-79, 2007.

In a previous study, we showed that operators of radiofrequency (RF) plastic sealers, RF operators (n = 35) had a lower heart rate during nighttime compared to a control group (n = 37). We have analyzed the heart rate variability (HRV) on the same group of people to better understand the possible underlying rhythm disturbances. We found a significantly increased total HRV and very low frequency (VLF) power during nighttime among the RF operators compared to a control group. Together with our previous finding of a significantly lower heart rate during nighttime among the RF operators compared to the controls, this finding indicates a relative increase in parasympathetic cardiac modulation in RF operators. This could in turn be due to an adaptation of the thermoregulatory system and the cardiac autonomic modulation to a long-term low-level thermal exposure in the RF operators.

Wu Y, Jia Y, Guo Y, Zheng Z, Influence of EMP on the nervous system of rats. ACTA Biophysica Sinica 15:152-157, 1999.

To explore the effects of electromagnetic pulse (EMP) exposure on the nervous system of rats, Wistar rats were divided into four groups: three exposure groups and one normal control group. The measurement of ability of learning of rats was carried out with a y-maze, followed by the detection of the content of neurotransmitters in different areas of cerebrum. Compared with control group, in the following three days of EMP exposure, the ability of learning of exposed groups was decreased ($P < 0.05$). For one day group, in hippocampus, the content of 5-HT and DOPAC increased ($P < 0.05$), and in hypothalamus, the content of dopamine increased ($P < 0.05$), while the content of Adr decreased ($p < 0.05$). the content of Adr and 5-HT in hippocampus of the second day group was reduced ($P < 0.05$). the content of Adr in hippocampus of the third day group was still lower than that of control group ($P < 0.05$). According to the results above, we can conclude that EMP exposure results in changes of the content of neurotransmitters in different cerebral areas of rats, lowering their ability of learning.

Xiong L, Sun CF, Zhang J, Gao YB, Wang LF, Zuo HY, Wang SM, Zhou HM, Xu XP, Dong J, Yao BW, Zhao L, Peng RY. Microwave Exposure Impairs Synaptic Plasticity in the Rat Hippocampus and PC12 Cells through Over-activation of the NMDA Receptor Signaling Pathway. Biomed Environ Sci. 28(1):13-24, 2015.

OBJECTIVE: The aim of this study is to investigate whether microwave exposure would affect the N-methyl-D-aspartate receptor (NMDAR) signaling pathway to establish whether this plays a role in synaptic plasticity impairment. METHODS: 48 male Wistar rats were exposed to 30 mW/cm2 microwave for 10 min every other day for three times. Hippocampal structure was observed through H&E staining and transmission electron microscope. PC12 cells were exposed to 30 mW/cm2 microwave for 5 min and the synapse morphology was visualized with scanning electron microscope and atomic force microscope. The release of amino acid neurotransmitters and calcium influx were detected. The expressions of several key NMDAR signaling molecules were evaluated. RESULTS: Microwave exposure caused injury in rat hippocampal structure and PC12 cells, especially the structure and quantity of synapses. The ratio of glutamic acid and gamma-aminobutyric acid neurotransmitters was increased and the intracellular calcium level was elevated in PC12 cells. A significant change in NMDAR subunits (NR1, NR2A, and NR2B) and related signaling molecules (Ca2+/calmodulin-dependent kinase II gamma and phosphorylated cAMP-response element binding protein) were examined. <u>CONCLUSION: 30 mW/cm2 microwave exposure resulted in alterations of synaptic structure, amino acid neurotransmitter release and calcium influx. NMDAR signaling molecules were closely associated with impaired synaptic plasticity.</u>

Yang X, He G, Hao Y, Chen C, Li M, Wang Y, Zhang G, Yu Z. The role of the JAK2-STAT3 pathway in pro-inflammatory responses of EMF-stimulated N9 microglial cells. J Neuroinflammation. 7:54, 2010.

BACKGROUND: In several neuropathological conditions, microglia can become overactivated and cause neurotoxicity by initiating neuronal damage in response to pro-inflammatory stimuli. Our previous studies have shown that exposure to electromagnetic fields (EMF) activates cultured microglia to produce tumor necrosis factor (TNF)-α and nitric oxide (NO) through signal transduction involving the activator of transcription STAT3. Here, we investigated the role of STAT3 signaling in EMF-induced microglial activation and pro-inflammatory responses in more detail than the previous study. **METHODS:** N9 microglial cells were treated with EMF exposure or a sham treatment, with or without pretreatment with an inhibitor (Pyridone 6, P6) of the Janus family of tyrosine kinases (JAK). The activation state of microglia was assessed via immunoreaction using the microglial marker CD11b. Levels of inducible nitric oxide synthase (iNOS), TNF-α and NO were measured using real-time reverse transcription-polymerase chain reaction (RT-PCR), enzyme-linked immunosorbent assay (ELISA) and the nitrate reductase method. Activation of JAKs and STAT3 proteins was evaluated by western blotting for specific tyrosine phosphorylation. The ability of STAT3 to bind to DNA was detected with an electrophoresis mobility shift assay (EMSA). **RESULTS:** EMF was found to significantly induce phosphorylation of JAK2 and STAT3, and DNA-binding ability of STAT3 in N9 microglia. In addition, EMF dramatically increased the expression of CD11b, TNF-α and iNOS, and the production of NO. P6 strongly suppressed the phosphorylation of JAK2 and STAT3 and diminished STAT3 activity in EMF-stimulated microglia. Interestingly, expression of CD11b as well as gene expression and production of TNF-α and iNOS were suppressed by P6 at 12 h, but not at 3 h, after EMF exposure. **CONCLUSIONS:** EMF exposure directly triggers initial activation of microglia and produces a significant pro-inflammatory response. Our findings confirm that the JAK2-STAT3 pathway may not mediate this initial microglial activation but does promote pro-inflammatory responses in EMF-stimulated microglial cells. Thus, the JAK2-STAT3 pathway might be a therapeutic target for reducing pro-inflammatory responses in EMF-activated microglia.

Ye J, Yao K, Lu D, Wu R, Jiang H. Low power density microwave radiation induced early changes in rabbit lens epithelial cells. Chin Med J (Engl) 114(12):1290-1294, 2001.

OBJECTIVE: To determine whether low power density microwave radiation can induce irreversible changes in rabbit lens epithelial cells (LECs) and the mechanisms of the changes. METHODS: One eye of each rabbit was exposed to 5 mW/cm2 or 10 mW/cm2 power density microwaves for 3 hours, while the contralateral eye served as a control. Annexin V-propidium iodide (PI) two-color flow cytometry (FCM) was used to detect the early changes in rabbit lens epithelial cells after radiation. RESULTS: Lots of rabbit LECs were in the initial phase of apoptosis in the 5 mW/cm2 microwave radiation group. A large number of cells became secondary necrotic cells, and severe damage could be found in the group exposed to 10 mW/cm2 microwave radiation. CONCLUSION: Low power densities of microwave radiation (5 mW/cm2 and 10 mW/cm2) can induce irreversible damage to rabbit LECs. This may be the non-thermal effect of microwave radiation.

Ye J, Yao K, Zeng Q, Lu D. Changes in gap junctional intercellular communication in rabbits lens epithelial cells induced by low power density microwave radiation. Chin Med J (Engl) 115(12):1873-1876, 2002.

OBJECTIVE: To demonstrate the changes in gap junctional intercellular communication (GJIC) mediated by low power density microwave radiation in rabbits lens epithelial cells (LECs) and its mechanisms. METHODS: Rabbits' eyes were exposed to 5 mW/cm(2) and 10 mW/cm(2) power densities of microwave radiation for 3 hours. The fluorescence-recovery-after-photobleaching (FRAP) method was used to determine the GJIC. The localization and function of connexin 43 in LECs was detected by laser scanning confocal microscopy. RESULTS: The GJIC of rabbits LECs was inhibited by microwave radiation especially in the 10 mW/cm(2) irradiated samples. A decrease in connexin 43-positive staining was seen in 5 mW/cm(2) x 3 h treated LECs. Intracellular space accumulation and cytoplasmic internalization were clearly demonstrated in 10 mW/cm(2) group. CONCLUSIONS: Low power densities microwave radiation (5 mW/cm(2) and 10 mW/cm(2)) induces damage to connexin 43 and inhibits the GJIC of rabbits LECs. These changes result in an osmotic imbalance within the lens and induce early cataract. 5 mW/cm(2) or 10 mW/cm(2) microwave radiation is cataractogenic.

Zhang X, Gao Y, Dong J, Wang S, Yao B, et al. (2014) The Compound Chinese Medicine “Kang Fu Ling” Protects against High Power Microwave-Induced Myocardial Injury. PLoS ONE 9(7): e101532.

doi:10.1371/journal.pone.0101532.

Background. The prevention and treatment of Microwave-caused cardiovascular injury remains elusive. This study investigated the cardiovascular protective effects of compound Chinese medicine "Kang Fu Ling" (KFL) against high power microwave (HPM)-induced myocardial injury and the role of the mitochondrial permeability transition pore (mPTP) opening in KFL protection. Methods. Male Wistar rats (100) were divided into 5 equal groups: no treatment, radiation only, or radiation followed by treatment with KFL at 0.75, 1.5, or 3 g/kg/day. Electrocardiography was used to Electrophysiological examination. Histological and ultrastructural changes in heart tissue and isolated mitochondria were observed by light microscope and electron microscopy. mPTP opening and mitochondrial membrane potential were detected by confocal laser scanning microscopy and fluorescence analysis. Connexin-43 (Cx-43) and endothelial nitric oxide synthase (eNOS) were detected by immunohistochemistry. The expression of voltage-dependent anion channel (VDAC) was detected by western blotting. Results. At 7 days after radiation, rats without KFL treatment showed a significantly lower heart rate ($P<0.01$) than untreated controls and a J point shift. Myocyte swelling and rearrangement were evident. Mitochondria exhibited rupture, and decreased fluorescence intensity, suggesting opening of mPTP and a consequent reduction in mitochondrial membrane potential. After treatment with 1.5 g/kg/day KFL for 7 d, the heart rate increased significantly ($P<0.01$), and the J point shift was reduced flavorfully ($P<0.05$) compared to untreated, irradiated rats; myocytes and mitochondria were of normal morphology. The fluorescence intensities of dye-treated mitochondria were also increased, suggesting inhibition of mPTP opening and preservation of the mitochondrial membrane potential. The microwave-induced decrease of Cx-43 and VDAC protein expression was significantly reversed. <u>Conclusion. Microwave radiation can cause electrophysiological, histological and ultrastructural changes in the heart. KFL at 1.5 g/kg/day had the greatest protective effect on these cardiovascular events. mPTP plays an important role in the protective effects of KFL against microwave-radiation-induced myocardial injury.</u>

Zhang Y, Li Z, Gao Y, Zhang C. Effects of fetal microwave radiation exposure on offspring behavior in mice. J Radiat Res. 2014 Oct 30. pii: rru097. [Epub ahead of print]

The recent rapid development of electronic communication techniques is resulting in a marked increase in exposure of humans to electromagnetic fields (EMFs). This has raised public concerns about the health hazards of long-term environmental EMF exposure for fetuses and children. Some studies have suggested EMF exposure in children could induce nervous system disorders. However, gender-dependent effects of microwave radiation exposure on cognitive dysfunction have not previously been reported. Here we investigated whether in utero exposure to 9.417-GHz microwave throughout gestation (Days 3.5-18) affected behavior, using the open field test (OFT), elevated-plus maze (EPM), tail suspension test (TST), forced swimming test (FST) and Morris water maze (MWM). We found that mice showed less movement in the center of an

open field (using the OFT) and in an open arm (using the EPM) after in utero exposure to 9.417-GHz radiation, which suggested that the mice had increased anxiety-related behavior. Mice demonstrated reduced immobility in TST and FST after in utero exposure to 9.417-GHz radiation, which suggested that the mice had decreased depression-related behavior. From the MWM test, we observed that male offspring demonstrated decreased learning and memory, while females were not affected in learning and memory, which suggested that microwaves had gender-dependent effects.

Zhao Z, Zhang S, Zho H, Zhang S, Su J, Li L, The effects of radiofrequency (< 30 MHz) radiation in humans. Rev Environ Health 10(3-4):213-215, 1994.

121 workers who were exposed to RFR (< 30 MHz) over one year were examined. They were divided into two groups: one group was exposed to high electric field intensity (> or = 100 V/m), another to low intensity (< 100 V/m) and both groups were compared to control subjects. No significant changes in the functioning of the autonomic nervous system and blood parameters (Hb, WBC and blood platelets) occurred in the exposed subjects of either group. Some changes in ECG (ST-T interval and abnormal heart rate) were observed in the group exposed to high intensity (> or = 100 V/m) radiation. 100 V/m is suggested as an exposure limit for RF (< 30 MHz) radiation.

Zhao Z, Zhang S, Wang S, Yao Z, Zho H, Tao S, Tao L, Exposure limits for ultra-short wave radiation in work environments. Rev Environ Health 10(3-4):217-220, 1994.

Exposure limit values for ultra-short wave radiation of humans were derived on the basis of epidemiological survey and experimental exposure of rabbits. Eighteen male rabbits were divided into 4 groups randomly. Three groups were irradiated with ultra-short waves (100 MHz) at 35, 1.5-3.5, and 0.07 mW/cm2 power density in an E-polarized TEM Cell at 24 +/- 4 degrees C ambient temperature. The last group in a sham chamber served as controls. Irradiation was performed 3 hours per day, 5 days per week for 24 weeks. Thermal effects occurred in the group irradiated at 35 mW/cm2. The thermal threshold limit value was set at 1.5 mW/cm2. An epidemiological survey was carried out on 136 factory workers and TV operators exposed over one year to ultra-short wave radiation at 0.2 mW/cm2. They were compared with 108 controls. The only complaint of the exposed group was neurosis. The exposure limit value (ELV) to short wave radiation was set at 0.2 mW/cm2 by using a 15- and 20-fold safety factor.

Wang H, Peng R, Zhao L, Wang S, Gao Y, Wang L, Zuo H, Dong J, Xu X, Zhou H, Su Z. The relationship between NMDA receptors and microwave induced learning and memory impairment: a long term observation on Wistar rats. Int J Radiat Biol. 2014 Nov 26:1-25. [Epub ahead of print]

Purpose: In the present study, we intended to investigate whether the high power microwave could cause the continuous disorders of learning and memory in Wistar rats and to explore the underlying mechanisms. Materials and methods: 80 Wistar rats were exposed to a **2.856 GHz pulsed microwave** source at a power density of 0 mW/cm^2 and 50 mW/cm^2 microwave for 6 min. The spatial memory ability, the structure of the hippocampus, contents of amino acids neurotransmitters in hippocampus and the expression of N-methyl-D-aspartic acid receptors (NMDAR) subunit 1, 2A and 2B (NR1, NR2A and NR2B) were detected at 1 m, 3 m, 6 m, 9 m, 12 m and 18 m after microwave exposure. Results: Our results showed that the microwave exposed rats showed consistent deficiencies in spatial learning and memory. The level of amino acid neurotransmitters also decreased after microwave radiation. The ratio of glutamate (Glu) and gammaaminobutyric acid (GABA) significantly decreased at 6 m. Besides, the hippocampus showed varying degrees of degeneration of neurons, increased postsynaptic density and blurred synaptic clefts in the exposure group. The NR1 and NR2B expression showed a significant decrease, especially the NR2B expression. Conclusions: This study indicated that the content of amino acids neurotransmitters, the expression of NMDAR subunits and the variation of hippocampal structure might contribute to the long term cognitive impairment after microwave exposure.

Wang H, Peng R, Zhou H, Wang S, Gao Y, Wang L, Yong Z, Zuo H, Zhao L, Dong J, Xu X, Su Z. Impairment of long-term potentiation induction is essential for the disruption of spatial memory after microwave exposure. Int J Radiat Biol. 2013 Jul 24. [Epub ahead of print]

Purpose: To assess the impact of microwave exposure on learning and memory and to explore the underlying mechanisms. Materials and methods: 100 Wistar rats were exposed to a **2.856 GHz pulsed microwave** field at average power densities of 0 mW/cm^2, 5 mW/cm^2, 10 mW/cm^2 and 50 mW/cm^2 for 6 min. The spatial memory was assessed by the Morris Water Maze (MWM) task. An in vivo study was conducted soon after microwave exposure to evaluate the changes of population spike (PS) amplitudes of long-term potentiation (LTP) in the medial perforant path (MPP)-dentate gyrus (DG) pathway. The structure of the hippocampus was observed by the light microscopy and the transmission electron microscopy (TEM) at 7 d after microwave exposure. Results: Our results showed that the rats exposed in 10 mW/cm^2 and 50 mW/cm^2 microwave displayed significant deficits in spatial learning and memory at 6 h, 1 d and 3 d after exposure. Decreased PS amplitudes were also found after 10 mW/cm^2 and 50 mW/cm^2 microwave exposure. In addition, varying degrees of degeneration of hippocampal neurons, decreased synaptic vesicles and blurred synaptic clefts were observed in the rats exposed in 10 mW/cm^2 and 50 mW/cm^2 microwave. Compared with the sham group, the rats exposed in 5 mW/cm^2 microwave showed no difference in the above experiments. Conclusions: This study suggested that impairment of LTP induction and the damages of hippocampal structure, especially changes of synapses, might contribute to cognitive impairment after microwave exposure.

Li H, Peng R, Wang C, Qiao S, Yong-Zou, Gao Y, Xu X, Wang S, Dong J, Zuo H, Li-Zhao, Zhou H, Wang L, Hu X. Alterations of cognitive function and 5-HT system in rats after long term microwave exposure. Physiol Behav. 2014 Dec 24. pii: S0031-9384(14)00663-5. doi: 10.1016/j.physbeh.2014.12.039. [Epub ahead of print]

The increased use of microwaves raises concerns about its impact on health including cognitive function in which neurotransmitter system plays an important role. In this study, we focused on the serotonergic system and evaluated the long term effects of chronic microwave radiation on cognition and correlated items. Wistar rats were exposed or sham exposed to 2.856GHz microwaves with the average power density of 5, 10, 20 or 30mW/cm^2 respectively for 6min three times a week up to 6weeks. At different time points after the last exposure, spatial learning and memory function, morphology structure of the hippocampus, electroencephalogram (EEG) and neurotransmitter content (amino acid and monoamine) of rats were tested. Above results raised our interest in serotonin system. Tryptophan hydroxylase 1 (TPH1) and monoamine oxidase (MAO), two important rate-limiting enzymes in serotonin synthesis and metabolic process respectively, were detected. Expressions of serotonin receptors including 5-HT$_{1A, 2A, 2C}$ receptors were measured. <u>We demonstrated that chronic exposure to microwave (2.856GHz, with the average power density of 5, 10, 20 and 30mW/cm^2) could induce dose-dependent deficit of spatial learning and memory in rats accompanied with inhibition of brain electrical activity, the degeneration of hippocampus neurons, and the disturbance of neurotransmitters, among which the increase of 5-HT occurred as the main long-term change that the decrease of its metabolism partly contributed to. Besides, the variations of 5-HT$_{1A}$R and 5-HT$_{2C}$R expressions were also indicated. The results suggested that in the long-term way, chronic microwave exposure could induce cognitive deficit and 5-HT system may be involved in it.</u>

Akoev IG, Pashovkina MS, Dolgacheva LP, Semenova TP, Kalmykov VL. [Enzymatic activity of some tissues and blood serum from animals and humans exposed to microwaves and hypothesis on the possible role of free radical processes in the nonlinear effects and modification of emotional behavior of animals] Radiats Biol Radioecol 42(3):322-330, 2002. [Article in Russian]

The dependence of activities of actomyosin ATPase, alkaline phosphatase, aspartataminotranspherase, monoaminoxidase and that of affective rat behavior on frequency of modulation of microwaves (0.8-10 microW/cm2) was explored at short-time actions. Series of nonlinear phenomenons, inexplicable from positions of the energy approaches are revealed, The working hypothesis explaining opportunity of high performance of weak and super-weak microwaves and other revealed phenomena by resonance interaction of such electromagnetic radiofrequency radiation with paramagnetic molecules of biological tissues was proposed. This resonance interaction activate free radicals and initiate autosupporting and auto-intensifying of chain chemical reactions. The spontaneous autocatalytic oxidation of catecholamines enlarges a common pool of free radicals, capable to participate in such enhanced generating. The protective role of monoaminoxidase is postulated. Monoaminoxidase is basically located on an outer surface of mitochondrias and it is deaminating monoamines. The deaminating prevents penetration of catecholamines inside of mitochondrias and their quinoid oxidation there with formation of free-radical semi-quinons, capable to destroy system of ATP synthesis. These inferences are obliquely confirmed by the experimentally revealed correlation between activity of monoaminoxidase and integrative activity of the rat brain.

Chen YB, Li J, Liu JY, Zeng LH, Wan Y, Li YR, Ren D, Guo GZ.Effect of Electromagnetic Pulses (EMP) on associative learning in mice and a preliminary study of mechanism. Int J Radiat Biol. 87(12):1147-1154, 2011.

PURPOSE: To investigate the effects of electromagnetic pulses (EMP) on associative learning in mice and test a preliminary mechanism for these effects. MATERIALS AND METHODS: A tapered parallel plate gigahertz transverse electromagnetic (GTEM) cell with a flared rectangular coaxial transmission line was used to expose male BALB/c mice to EMP (peak-intensity 400 kV/m, rise-time 10 ns, pulse-width 350 ns, 0.5 Hz and total 200 pulses). Concurrent sham-exposed mice were used as a control. Associative learning, oxidative stress in the brain, serum chemistry and the protective action of tocopherol monoglucoside (TMG) in mice were measured, respectively. RESULTS: (1) Twelve hour and 1 day post EMP exposure associative learning was reduced significantly compared with sham control ($p<0.05$) but recovered at 2 d post EMP exposure. (2) Compared with the sham control, lipid peroxidation of brain tissue and chemiluminescence (CL) intensity increased significantly ($p<0.05$), while the activity of the antioxidant enzymes Superoxide Dismutase [SOD], Glutathione [GSH], Glutathione Peroxidase [GSH-Px], Catalase [CAT]) decreased significantly ($p<0.05$) at 3 h, 6 h, 12 h and 1 d post EMP exposure. All these parameters recovered at 2 d post EMP exposure. (3) No significant differences between the sham control group and EMP exposed group were observed in serum cholesterol and triglycerides. (4) Pretreatment of mice with TMG showed protective effects to EMP exposure. CONCLUSIONS: EMP exposure significantly decreased associative learning in mice and TMG acted as an effective protective agent from EMP exposure. This mechanism could involve an increase of oxidative stress in brain by EMP exposure.

Maaroufi K, Save E, Poucet B, Sakly M, Abdelmelek H, Had-Aissouni L. Oxidative stress and prevention of the adaptive response to chronic iron overload in the brain of young adult rats exposed to a 150 kilohertz electromagnetic field. Neuroscience. 186:39-47, 2011.

Iron surcharge may induce an oxidative stress-based decline in several neurological functions. In addition, electromagnetic fields (EMF) of frequencies up to about 100 kHz, emitted by electric/electronic devices, have been suggested to enhance free radical production through an iron dependent pathway. The purpose of this study was therefore to determine a possible relationship between iron status, exposure to EMF, and brain oxidative stress in young adult rats. Samples were micro-dissected from prefrontal cortex, hippocampus, striatum, and cerebellum after chronic saline or iron overload (IO) as well as after chronic sham exposure or exposure to a 150 kHz EMF or after combining EMF exposure with IO. The brain samples were used to monitor oxidative stress-induced lipid peroxidation and activity of the antioxidant enzymes superoxide dismutase and catalase. While IO did not induce any oxidative stress in young adult rats, it stimulated antioxidant defenses in the cerebellum and prefrontal cortex in particular. On the contrary, EMF exposure stimulated lipid peroxidation mainly in the cerebellum, without affecting antioxidant defenses. When EMF was coapplied with IO, lipid peroxidation was further increased as compared to EMF alone while the increase in antioxidant defenses triggered by the sole IO was abolished. These data suggest that EMF exposure may be harmful in young adults by impairing the antioxidant defenses directed at preventing iron-induced oxidative stress.

Belyaev IYa, Alipov YD, Shcheglov VS, Lystsov VN, Resonance effect of microwaves on the genome conformational state of E. coli cells. Z Naturforsch [C] 47(7-8):621-827, 1992.

The effect of low intensity microwaves on the conformational state of the genome of X-irradiated E. coli cells was studied by the method of viscosity anomalous time dependencies. It has been established that within the ranges of 51.62-51.84 GHz and 41.25-41.50 GHz the frequency dependence of the observed effect has a resonance nature with a resonance half-width of the order of 100 MHz. The power dependence of the microwave effect within the range of 0.1-200 microW/cm2 has shown that a power density of 1 microW/cm2 is sufficient to suppress radiation-induced repair of the genome conformational state. The effect of microwave suppression of repair is well reproduced and does not depend on the sequence of cell exposure to X-rays and microwave radiation in the millimeter band. The results obtained indicate the role of the cell genome in the resonant interaction of cells with low intensity millimeter waves.

Grigor'ev IuG, Luk'ianova SN, Makarov VP, Rynskov VV, Moiseeva NV, [Motor activity of rabbits in conditions of chronic low-intensity pulse microwave irradiation]. Radiats Biol Radioecol 35(1):29-35, 1995. [Article in Russian]

Motor activity of rabbits under daily thirty-minute irradiation (1.5 GHz, pulse duration 16 ms, pulse recurrence frequency 0.12 Hz, pulse intensity 0.3 mw/cm2) for one month was studied. From 14th day the reliable disadaptation changes such as an anxiety and alarm reaction were found. The importance of prolonged irradiation is noted.

Chen YB, **Li J**, **Qi Y**, **Miao X**, **Zhou Y**, **Ren D**, **Guo GZ**. **The effects of** electromagnetic **pulses (EMP) on the bioactivity of insulin and a preliminary study of mechanism.** **Int J Radiat Biol.** **86(1):22-26, 2010.**

*PURPOSE: To investigate the effects of **electromagneticpulse** (EMP) exposure on the bioactivity of insulin and a preliminary mechanism for these effects.MATERIALS AND METHODS: A tapered parallel plate Gigahertz Transverse **Electromagnetic** (GTEM) cell with a flared rectangular coaxial transmission line was used to expose the insulin solution to EMP. Concurrent sham-exposed insulin solutions were used as a control. The effect of EMP-exposed insulin on fasting blood glucose levels of type I diabetes model mice, the effect of EMP on binding affinity between insulin and its receptor and the effect of EMP on insulin's fluorescence intensity were detected, respectively.RESULTS: (i) After EMP exposure, compared with sham-exposed insulin, the bioactivity of insulin in decreasing fasting blood glucose levels in type I diabetes model mice was reduced significantly (p = 0.023). (ii) Compared with sham-exposed insulin group, the percentage fluorescein isothiocyannate (FITC) labelling of HL-7702 cells was significantly reduced in the EMP-exposed insulin group (22.7-13.8%, respectively). (iii) Compared with sham-exposed insulin, the fluorescence intensity was significantly reduced in EMP-exposed insulin (p < 0.001).CONCLUSIONS: EMP exposure significantly decreased the bioactivity of insulin to reduce the blood glucose levels in type I diabetic mice. This could be due to a decreased binding affinity between insulin and its receptor. This mechanism could involve an alteration of insulin's' conformation caused by EMP exposure.*

D'Andrea JA, Thomas A, Hatcher DJ, Rhesus monkey behavior during exposure to high-peak-power 5.62-GHz microwave pulses. Bioelectromagnetics 15(2):163-176, 1994.

Limits on the exposure to high-peak-power, short-duration microwave pulses have only recently been adopted. Additional data, however, are needed to understand the effects that may be produced by exposure to high-peak-power pulsed microwaves. Four male rhesus monkeys (Macaca mulatta) were trained on an operant task for food pellet reward to investigate the behavioral effects of very high-peak-power 5.62 GHz microwaves. The operant task required monkeys to pull one plastic lever on a variable interval schedule (VI-25 s) and then respond to color signals and pull a second lever to obtain food. The monkeys were conditioned to perform a color discrimination task using one of three colors displayed by a fiber-optic cable. A red signal was the discriminative stimulus for responding on the first lever. A response on the second lever when a green signal was presented (1 s duration) delivered a food pellet. If a response on the second lever was made in the presence of a white signal, a 30-s timeout occurred. While performing the behavioral task, the monkeys were exposed to microwave pulses produced by either a military radar (FPS-26A) operating at 5.62 GHz or the same radar coupled to a Stanford linear energy doubler (SLED) pulse-forming device (ITT-2972) that enhanced peak power by a factor of nine by adding a high power pulse to the radar pulse. The effects of both types of pulses were compared to sham exposure. Peak field power densities tested were

518, 1270, and 2520 W/cm2 for SLED pulses and 56, 128, and 277 W/cm2 for the radar pulses. The microwave pulses (radar or SLED) were delivered at 100 pps (2.8 microseconds radar pulse duration; approximately 50 ns SLED pulse duration) for 20 min and produced averaged whole-body SARs of 2, 4, or 6 W/kg. Compared to sham exposures, significant alterations of lever responding, reaction time, and earned food pellets occurred during microwave exposure at 4 and 6 W/kg but not at 2 W/kg. There were no differences between radar or SLED pulses in producing behavioral effects.

Li H, Peng R, Wang C, Qiao S, Yong-Zou, Gao Y, Xu X, Wang S, Dong J, Zuo H, Li-Zhao, Zhou H, Wang L, Hu X. Alterations of cognitive function and 5-HT system in rats after long term microwave exposure. Physiol Behav. 2014 Dec 24. pii: S0031-9384(14)00663-5. doi: 10.1016/j.physbeh.2014.12.039. [Epub ahead of print]

The increased use of microwaves raises concerns about its impact on health including cognitive function in which neurotransmitter system plays an important role. In this study, we focused on the serotonergic system and evaluated the long term effects of chronic microwave radiation on cognition and correlated items. Wistar rats were exposed or sham exposed to 2.856GHz microwaves with the average power density of 5, 10, 20 or 30mW/cm^2 respectively for 6min three times a week up to 6weeks. At different time points after the last exposure, spatial learning and memory function, morphology structure of the hippocampus, electroencephalogram (EEG) and neurotransmitter content (amino acid and monoamine) of rats were tested. Above results raised our interest in serotonin system. Tryptophan hydroxylase 1 (TPH1) and monoamine oxidase (MAO), two important rate-limiting enzymes in serotonin synthesis and metabolic process respectively, were detected. Expressions of serotonin receptors including 5-HT$_{1A, 2A, 2C}$ receptors were measured. We demonstrated that chronic exposure to microwave (2.856GHz, with the average power density of 5, 10, 20 and 30mW/cm^2) could induce dose-dependent deficit of spatial learning and memory in rats accompanied with inhibition of brain electrical activity, the degeneration of hippocampus neurons, and the disturbance of neurotransmitters, among which the increase of 5-HT occurred as the main long-term change that the decrease of its metabolism partly contributed to. Besides, the variations of 5-HT$_{1A}$R and 5-HT$_{2C}$R expressions were also indicated. The results suggested that in the long-term way, chronic microwave exposure could induce cognitive deficit and 5-HT system may be involved in it.

Hinrikus H, Bachmann M, Lass J, Tomson R, Tuulik V. Effect of 7, 14 and 21 Hz modulated 450 MHz microwave radiation on human electroencephalographic rhythms. Int J Radiat Biol. 84(1):69-79, 2008.

PURPOSE: The aim of this study was to evaluate the effect of microwaves modulated at different frequencies on human electroencephalographic (EEG) rhythms. MATERIALS AND METHODS: Thirteen healthy volunteers were exposed to microwaves (450 MHz) pulse-modulated at frequencies of 7, 14 and 21 Hz. The field power density at the scalp was 0.16 mW/cm2. Our experimental protocol consisted of two five-cycle (1 min on and 1 min off) series of exposures at fixed modulation frequencies. A relative change in the EEG power with and without exposure was used as a quantitative measure. EEG frequencies recorded in the theta (4-6.8 Hz), alpha (8-13 Hz), betal (15-20 Hz), and beta2 (22-38 Hz) bands were analyzed. RESULTS: Modulated microwaves caused an increase in the average EEG alpha (17%) and beta (7%) power but the theta rhythm remained unaffected. Increases in the EEG alpha and beta power were statistically significant during the first half-period of the exposure interval (30 s) at the modulation frequencies of 14 and 21 Hz. Differences were found in individual sensitivity to exposure. Increases in the EEG beta power appeared statistically significant in the case of four subjects. CONCLUSIONS: Our findings suggest that the effect of the 450 MHz microwave radiation modulated at 7, 14 and 21 Hz varies depending on the modulation frequency. The microwave exposure modulated at 14 and 21 Hz enhanced the EEG power in the alpha and beta frequency bands, whereas no enhancement occurred during exposure to the modulation frequency of 7 Hz.

Hinrikus H, Bachmann M, Lass J, Karai D, Tuulik V. Effect of low frequency modulated microwave exposure on human EEG: individual sensitivity. Bioelectromagnetics. 29(7):527-538, 2008.

The aim of this study was to evaluate the effect of modulated microwave exposure on human EEG of individual subjects. The experiments were carried out on four different groups of healthy volunteers. The 450 MHz microwave radiation modulated at 7 Hz (first group, 19 subjects), 14 and 21 Hz (second group, 13 subjects), 40 and 70 Hz (third group, 15 subjects), 217 and 1000 Hz (fourth group, 19 subjects) frequencies was applied. The field power density at the scalp was 0.16 mW/cm(2). The calculated spatial peak SAR averaged over 1 g was 0.303 W/kg. Ten cycles of the exposure (1 min off and 1 min on) at fixed modulation frequencies were applied. All subjects completed the experimental protocols with exposure and sham. The exposed and sham-exposed subjects were randomly assigned. A computer also randomly assigned the succession of modulation frequencies. Our results showed that microwave exposure increased the EEG energy. Relative changes in the EEG beta1 power in P3-P4 channels were selected for evaluation of individual sensitivity. The rate of subjects significantly affected is similar in all groups except for the 1000 Hz group: in first group 3 subjects (16%) at 7 Hz modulation; in second group 4 subjects (31%) at 14 Hz modulation and 3 subjects (23%) at 21 Hz modulation; in third group 3 subjects (20%) at 40 Hz and 2 subjects (13%) at 70 Hz modulation; in fourth group 3 subjects (16%) at 217 Hz and 0 subjects at 1000 Hz modulation frequency.